DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Sections 8.3.2 through 8.3.4.4

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

DISCLAIMER

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, mark, manufacturer, or otherwise, does not necssarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The view and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

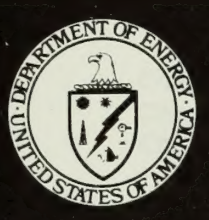
Printed in the United States of America

Available from:

U.S. Department of Energy
Office of Scientific and Technical Information
Post Office Box 62
Oak Ridge, TN 37831

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)



Site Characterization Plan

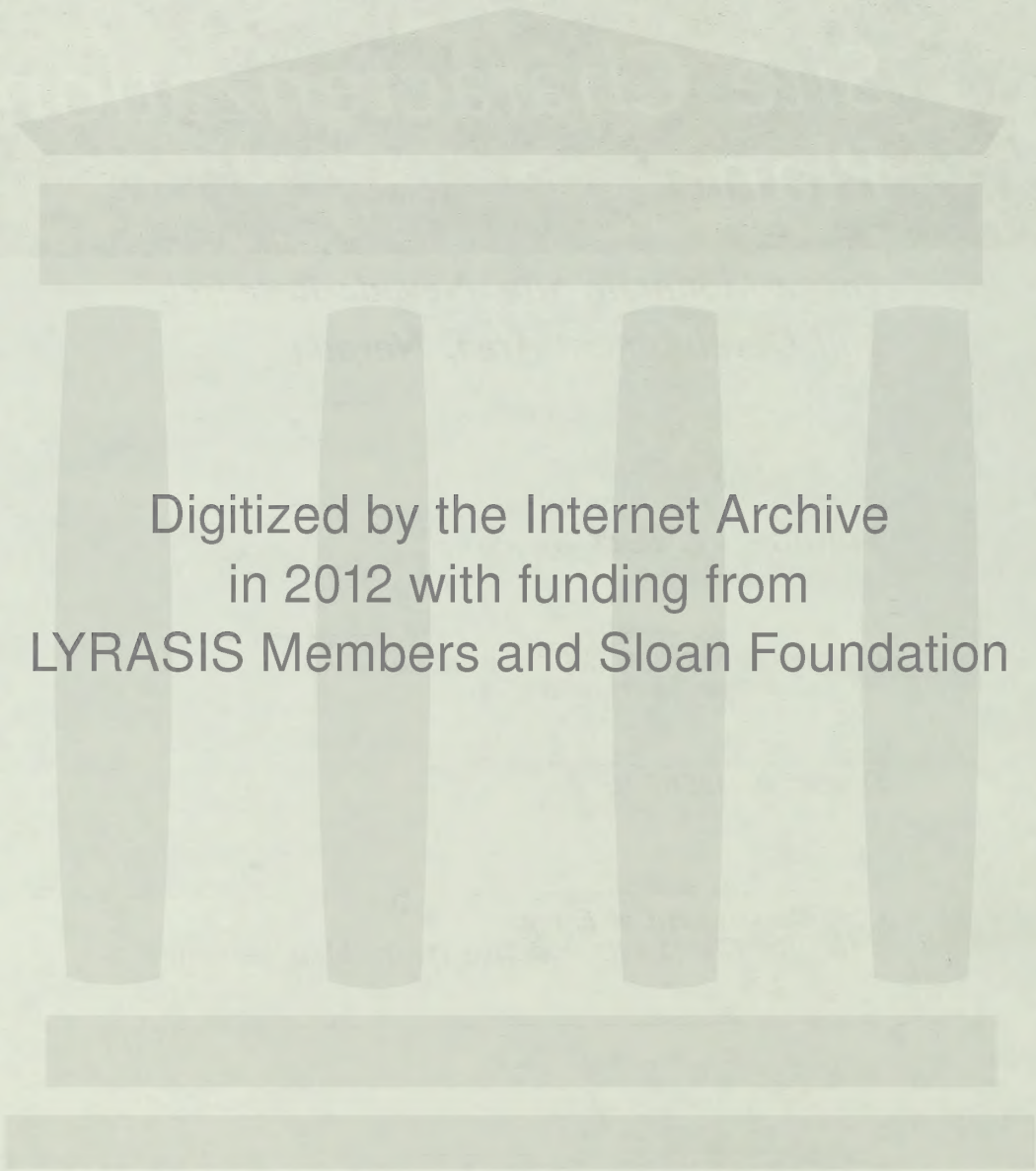
Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Sections 8.3.2 through 8.3.4.4

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management



Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://archive.org/details/sitecharacteriza00vipb

DOCUMENT ORGANIZATION

VOLUME I

Introduction

Part A: Description of the mined geologic disposal system introduction
Chapter 1--Geology
Chapter 2--Geoengineering

VOLUME II

Chapter 3--Hydrology
Chapter 4--Geochemistry
Chapter 5--Climatology and meteorology

VOLUME III

Chapter 6--Conceptual design of a repository
Chapter 7--Waste package

VOLUME IV

Part B: Site characterization program (Chapter 8)
8.0 Introduction
8.1 Rationale
8.2 Issues
8.3 Planned tests, analyses, and studies

8.3.1 Site program
8.3.1.1 Site overview
8.3.1.2 Geohydrology
8.3.1.3 Geochemistry
8.3.1.4 Rock characteristics

VOLUME V

8.3.1.5 Climate
8.3.1.6 Erosion
8.3.1.7 Rock dissolution
8.3.1.8 Postclosure tectonics
8.3.1.9 Human interference
8.3.1.10 Population density and distribution
8.3.1.11 Land ownership and mineral rights
8.3.1.12 Meteorology
8.3.1.13 Offsite installations
8.3.1.14 Surface characteristics
8.3.1.15 Thermal and mechanical properties
8.3.1.16 Preclosure hydrology
8.3.1.17 Preclosure tectonics

VOLUME VI

8.3.2 Repository program
8.3.2.1 Repository overview

DOCUMENT ORGANIZATION (continued)

8.3.2.2 Configuration of underground facilities (postclosure)
8.3.2.3 Repository design criteria for radiological safety
8.3.2.4 Nonradiological health and safety
8.3.2.5 Preclosure design and technical feasibility

8.3.3 Seal program
8.3.3.1 Seal overview
8.3.3.2 Seal characteristics

8.3.4 Waste package
8.3.4.1 Waste package overview
8.3.4.2 Waste package characteristics (postclosure)
8.3.4.3 Waste package characteristics (preclosure)
8.3.4.4 Waste package production technologies

VOLUME VII

8.3.5 Performance assessment program
8.3.5.1 Strategy for preclosure performance assessment
8.3.5.2 Waste retrievability
8.3.5.3 Public radiological exposures--normal conditions
8.3.5.4 Worker radiological safety--normal conditions
8.3.5.5 Accidental radiological releases
8.3.5.6 Higher-level findings--preclosure radiological safety
8.3.5.7 Higher-level findings--ease and cost of construction
8.3.5.8 Strategy for postclosure performance assessment
8.3.5.9 Containment by waste package
8.3.5.10 Engineered barrier system release rates
8.3.5.11 Seal performance
8.3.5.12 Ground-water travel time
8.3.5.13 Total system performance
8.3.5.14 Individual protection
8.3.5.15 Ground-water protection
8.3.5.16 Performance confirmation
8.3.5.17 NRC siting criteria
8.3.5.18 Higher level findings--postclosure system and technical guidelines
8.3.5.19 Completed analytical techniques
8.3.5.20 Analytical techniques requiring development

VOLUME VIII

8.4 Planned site preparation activities
8.4.1 Introduction
8.4.2 Description and location of characterization operations
8.4.3 Potential impacts of site characterization activities on postclosure performance objectives

DOCUMENT ORGANIZATION (continued)

8.5 Milestones, decision points, and schedule
8.6 Quality assurance program
8.7 Decontamination and decommissioning

Glossary and acronyms

VOLUME IX

Index

TABLE OF CONTENTS

VOLUME VI

	Page
8.3.2 Repository program	8.3.2- 1
8.3.2.1 Overview of repository program	8.3.2.1- 1
8.3.2.1.1 Verification or measurement of host-rock environment	8.3.2.1- 8
8.3.2.1.1.1 Pre-waste-emplacement environment	8.3.2.1- 9
8.3.2.1.1.2 Post-subsurface-excavation environment	8.3.2.1- 11
8.3.2.1.1.3 Post-waste-emplacement environment	8.3.2.1- 12
8.3.2.1.2 Coupled interaction tests	8.3.2.1- 13
8.3.2.1.3 Design improvement activities and tests	8.3.2.1- 18
8.3.2.1.4 Repository modeling	8.3.2.1- 19
8.3.2.1.4.1 Geomechanical analyses	8.3.2.1- 21
8.3.2.1.4.2 Seismic analyses	8.3.2.1- 24
8.3.2.1.4.3 Ventilation analyses	8.3.2.1- 24
8.3.2.1.4.4 Safety analyses	8.3.2.1- 25
8.3.2.2 Issue resolution strategy for Issue 1.11: Have the characteristics and configurations of the repository and repository engineered barriers been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.133 and (b) provide information for the resolution of the performance issues	8.3.2.2- 1
8.3.2.2.1 Information Need 1.11.1: Site characterization information needed for design	8.3.2.2- 23
8.3.2.2.1.1 Design Activity 1.11.1.1: Compile a comprehensive list of all the information required from site characterization to resolve this issue	8.3.2.2- 39
8.3.2.2.1.2 Design Activity 1.11.1.2: Determine adequacy of existing site data	8.3.2.2- 39
8.3.2.2.1.3 Design Activity 1.11.1.3: Document reference three-dimensional thermal/ mechanical stratigraphy of Yucca Mountain	8.3.2.2- 40
8.3.2.2.1.4 Design Activity 1.11.1.4: Preparation of reference properties for the reference information base	8.3.2.2- 40
8.3.2.2.1.5 Application of results	8.3.2.2- 40
8.3.2.2.2 Information Need 1.11.2: Characteristics of waste package needed for design of the underground facility	8.3.2.2- 41

TABLE OF CONTENTS (continued)

Page

8.3.2.2.2.1 Design Activity 1.11.2.1: Compile waste package information needed for repository design 8.3.2.2- 44
8.3.2.2.2.2 Application of results 8.3.2.2- 44
8.3.2.2.3 Information Need 1.11.3: Design concepts for orientation, geometry, layout, and depth of the underground facility that contribute to waste containment and isolation including flexibility to accommodate site-specific conditions 8.3.2.2- 44
8.3.2.2.3.1 Design Activity 1.11.3.1: Area needed determination 8.3.2.2- 52
8.3.2.2.3.2 Design Activity 1.11.3.2: Usable area and flexibility evaluation 8.3.2.2- 53
8.3.2.2.3.3 Design Activity 1.11.3.3: Vertical and horizontal emplacement orientation decision 8.3.2.2- 53
8.3.2.2.3.4 Design Activity 1.11.3.4: Drainage and moisture control plan 8.3.2.2- 53
8.3.2.2.3.5 Design Activity 1.11.3.5: Criteria for contingency plan 8.3.2.2- 54
8.3.2.2.3.6 Application of results 8.3.2.2- 54
8.3.2.2.4 Information Need 1.11.4: Design constraints to limit water usage and potential chemical changes 8.3.2.2- 54
8.3.2.2.4.1 Design Activity 1.11.4.1: Chemical changes resulting from the use of construction materials 8.3.2.2- 59
8.3.2.2.4.2 Design Activity 1.11.4.2: Material inventory criteria 8.3.2.2- 59
8.3.2.2.4.3 Design Activity 1.11.4.3: Water management criteria 8.3.2.2- 59
8.3.2.2.4.4 Application of results 8.3.2.2- 59
8.3.2.2.5 Information Need 1.11.5: Design constraints to limit excavation-induced changes in rock mass permeability 8.3.2.2- 60
8.3.2.2.5.1 Design Activity 1.11.5.1: Excavation methods criteria 8.3.2.2- 64
8.3.2.2.5.2 Design activity 1.11.5.2: Long-term subsidence control strategy 8.3.2.2- 64
8.3.2.2.5.3 Application of results 8.3.2.2- 64
8.3.2.2.6 Information Need 1.11.6: Repository thermal loading and predicted thermal and thermo-mechanical response of the host rock 8.3.2.2- 65

TABLE OF CONTENTS (continued)

	Page
8.3.2.2.6.1 Design Activity 1.11.6.1: Thermal loading for underground facility	8.3.2.2- 73
8.3.2.2.6.2 Design Activity 1.11.6.2: Borehole spacing strategy	8.3.2.2- 74
8.3.2.2.6.3 Design Activity 1.11.6.3: Sensitivity studies	8.3.2.2- 74
8.3.2.2.6.4 Design Activity 1.11.6.4: Strategy for containment enhancement	8.3.2.2- 74
8.3.2.2.6.5 Design Activity 1.11.6.5: Reference calculations	8.3.2.2- 74
8.3.2.2.6.6 Application of results	8.3.2.2- 75
8.3.2.2.7 Information Need 1.11.7: Reference post-closure repository design	8.3.2.2- 75
8.3.2.2.7.1 Design Activity 1.11.7.1: Reference postclosure repository design	8.3.2.2- 77
8.3.2.2.7.2 Design Activity 1.11.7.2: Documentation of compliance	8.3.2.2- 77
8.3.2.2.7.3 Application of results	8.3.2.2- 77
8.3.2.2.8 Schedule for configuration of underground facilities	8.3.2.2- 78
8.3.2.3 Issue resolution strategy for Issue 2.7: Have the characteristics and configurations of the repository been adequately established to (a) show compliance with the preclosure design criteria of 10 CFR 60.130 through 60.133 and (b) provide information for the resolution of the performance issues?	8.3.2.3- 1
8.3.2.3.1 Information Need 2.7.1: Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to radiological protection have been met	8.3.2.3- 39
8.3.2.3.1.1 Design Activity 2.7.1.1: Design evaluation for compliance with radiological safety design criteria and performance goals	8.3.2.3- 42
8.3.2.3.1.2 Application of results	8.3.2.3- 42
8.3.2.3.2 Information Needs 2.7.2 and 2.7.3: (1) Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to the design and protection of structures, systems, and components important to safety have been met, and (2) Determination that the design criteria in 10 CFR 60.131 through 60.133	

TABLE OF CONTENTS (continued)

Page

and any appropriate additional design objectives pertaining to criticality control have been met 8.3.2.3- 43
8.3.2.3.2.1 Application of results 8.3.2.3- 45
8.3.2.3.3 Schedule for repository design criteria for radiological safety 8.3.2.3- 45
8.3.2.4 Issue resolution strategy for Issue 4.2: Are the repository design and operating procedures developed to ensure nonradiological health and safety of workers adequately established for the resolution of the performance issues? 8.3.2.4- 1
8.3.2.4.1 Information Need 4.2.1: Site and performance assessment information needed for design 8.3.2.4- 23
8.3.2.4.1.1 Design activity to verify access and drift usability 8.3.2.4- 27
8.3.2.4.1.2 Design activity to verify air quality and ventilation 8.3.2.4- 30
8.3.2.4.1.3 Application of results 8.3.2.4- 30
8.3.2.4.2 Schedule for nonradiological health and safety (Issue 4.2) 8.3.2.4- 31
8.3.2.5 Issue resolution strategy for Issue 4.4: Are the technologies of repository construction, operation, closure, and decommissioning adequately established for the resolution of the performance issues? 8.3.2.5- 1
8.3.2.5.1 Information Need 4.4.1: Site and performance assessment information needed for design 8.3.2.5- 35
8.3.2.5.1.1 Application of results 8.3.2.5- 38
8.3.2.5.2 Information Need 4.4.2: Characteristics and quantities of waste and waste packages needed for design 8.3.2.5- 38
8.3.2.5.2.1 Application of results 8.3.2.5- 42
8.3.2.5.3 Information Need 4.4.3: Plan for repository operations during construction, operation, closure, and decommissioning 8.3.2.5- 43
8.3.2.5.3.1 Design Activity 4.4.3.1: Operations plan to accompany the advanced conceptual design 8.3.2.5- 45
8.3.2.5.3.2 Design Activity 4.4.3.2: Operations plan to accompany the license application design 8.3.2.5- 45
8.3.2.5.3.3 Application of results 8.3.2.5- 46
8.3.2.5.4 Information Need 4.4.4: Repository design requirements for construction, operation, closure, and decommissioning 8.3.2.5- 47

TABLE OF CONTENTS (continued)

	Page
8.3.2.5.4.1 Design Activity 4.4.4.1: Repository design requirements (RDR) for license application design	8.3.2.5- 51
8.3.2.5.4.2 Application of results	8.3.2.5- 51
8.3.2.5.5 Information Need 4.4.5: Reference preclosure repository design	8.3.2.5- 52
8.3.2.5.5.1 Application of results	8.3.2.5- 56
8.3.2.5.6 Information Need 4.4.6: Development and demonstration of required equipment	8.3.2.5- 57
8.3.2.5.6.1 Application of results	8.3.2.5- 60
8.3.2.5.7 Information Need 4.4.7: Design analyses, including those addressing impacts of surface conditions, rock characteristics, hydrology, and tectonic activity	8.3.2.5- 61
8.3.2.5.7.1 Application of results	8.3.2.5- 84
8.3.2.5.8 Information Need 4.4.8: Identification of technologies for surface facility construction, operation, closure, and decommissioning	8.3.2.5- 85
8.3.2.5.8.1 Application of results	8.3.2.5- 88
8.3.2.5.9 Information Need 4.4.9: Identification of technologies for underground facility construction, operation, closure, and decommissioning	8.3.2.5- 88
8.3.2.5.9.1 Application of results	8.3.2.5- 95
8.3.2.5.10 Information Need 4.4.10: Determination that the seals for shafts, drifts, and boreholes can be placed with reasonably available technology	8.3.2.5- 96
8.3.2.5.10.1 Application of results	8.3.2.5- 97
8.3.2.5.11 Schedule for preclosure design and technical feasibility	8.3.2.5- 97
8.3.3 Seal program	8.3.3- 1
8.3.3.1 Overview of the seal program	8.3.3.1- 1
8.3.3.1.1 Seal environment	8.3.3.1- 4
8.3.3.1.2 Seal components	8.3.3.1- 4
8.3.3.1.3 Seal designs	8.3.3.1- 8
8.3.3.1.4 Seal modeling	8.3.3.1- 8
8.3.3.2 Issue resolution strategy for Issue 1.12: Have the characteristics and configurations of the shaft and borehole seals been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.134 and (b) provide information for the resolution of the performance issues?	8.3.3.2- 1

TABLE OF CONTENTS (continued)

Page

8.3.3.2.1 Information Need 1.12.1: Site, waste package, and underground facility information needed for design of seals and their placement methods 8.3.3.2- 32
8.3.3.2.1.1 Application of results 8.3.3.2- 36
8.3.3.2.2 Information Need 1.12.2: Materials and characteristics of seals for shafts, drifts, and boreholes 8.3.3.2- 36
8.3.3.2.2.1 Study 1.12.2.1: Seal material properties development 8.3.3.2- 39
8.3.3.2.2.1.1 Activity 1.12.2.1.1: Detailed property determination of cementitious-based and earthen materials 8.3.3.2- 39
8.3.3.2.2.1.2 Activity 1.12.2.1.2: Hydraulic conductivity and consolidation testing of crushed tuff 8.3.3.2- 40
8.3.3.2.2.2 Design Activity 1.12.2.2: A degradation model for cementitious materials emplaced in a tuffaceous environment 8.3.3.2- 40
8.3.3.2.2.3 Study 1.12.2.3: In situ testing of seal components 8.3.3.2- 41
8.3.3.2.2.4 Application of results 8.3.3.2- 62
8.3.3.2.3 Information Need 1.12.3: Placement method for seals for shafts, drifts, and boreholes 8.3.3.2- 62
8.3.3.2.3.1 Application of results 8.3.3.2- 64
8.3.3.2.4 Information Need 1.12.4: Reference design of seals for shafts, drifts, and boreholes . . 8.3.3.2- 64
8.3.3.2.4.1 Design Activity 1.12.4.1: Development of the advanced conceptual design (ACD) for sealing 8.3.3.2- 65
8.3.3.2.4.1.1 Design Subactivity 1.12.4.1.1: Define subsystem design requirements 8.3.3.2- 65
8.3.3.2.4.1.2 Design Subactivity 1.12.4.1.2: Perform trade-off studies to support advanced conceptual design development 8.3.3.2- 66
8.3.3.2.4.1.3 Design Subactivity 1.12.4.1.3: Develop advanced conceptual design for seals 8.3.3.2- 67
8.3.3.2.4.2 Design Activity 1.12.4.2: Development of the license application design for sealing 8.3.3.2- 68

TABLE OF CONTENTS (continued)

	Page
8.3.3.2.4.2.1 Design Subactivity 1.12.4.2.1: Define subsystem design requirements	8.3.3.2- 68
8.3.3.2.4.2.2 Design Subactivity 1.12.4.2.2: Perform trade-off studies to support license application design development	8.3.3.2- 68
8.3.3.2.4.2.3 Design Subactivity 1.12.4.2.3: Develop license application design for seals	8.3.3.2- 69
8.3.3.2.4.3 Application of results	8.3.3.2- 69
8.3.3.2.5 Schedule for seal characteristics (Issue 1.12)	8.3.3.2- 70
8.3.4 Waste package program	8.3.4- 1
8.3.4.1 Overview	8.3.4.1- 1
8.3.4.1.1 Waste package environment	8.3.4.1- 4
8.3.4.1.2 Waste package components	8.3.4.1- 5
8.3.4.1.3 Waste package designs	8.3.4.1- 5
8.3.4.1.4 Waste package modeling	8.3.4.1- 7
8.3.4.2 Issue resolution strategy for Issue 1.10: Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.135 and (b) provide information to support resolution of the performance issues?	8.3.4.2- 1
8.3.4.2.1 Information Need 1.10.1: Design information needed to comply with postclosure criteria from 10 CFR 60.135(a) for consideration of the interactions between the waste package and its environment	8.3.4.2- 33
8.3.4.2.1.1 Design Activity 1.10.1.1: Consideration of 10 CFR 60.135(a) factors	8.3.4.2- 34
8.3.4.2.1.2 Application of results	8.3.4.2- 35
8.3.4.2.2 Information Need 1.10.2: Reference waste package designs	8.3.4.2- 35
8.3.4.2.2.1 Application of results	8.3.4.2- 36
8.3.4.2.3 Information Need 1.10.3: Reference waste package emplacement configurations	8.3.4.2- 37
8.3.4.2.3.1 Application of results	8.3.4.2- 39
8.3.4.2.4 Information Need 1.10.4: Postemplacement near-field environment	8.3.4.2- 39
8.3.4.2.4.1 Study 1.10.4.1: Characterize chemical and mineralogical changes in the postemplacement environment	8.3.4.2- 42

TABLE OF CONTENTS (continued)

	Page
8.3.4.2.4.1.1 Activity 1.10.4.1.1: Rock-water interactions at elevated temperatures	8.3.4.2- 42
8.3.4.2.4.1.2 Activity 1.10.4.1.2: Effect of grout, concrete, and other repository materials on water composition	8.3.4.2- 45
8.3.4.2.4.1.3 Activity 1.10.4.1.3: Composition of vadose water from the waste package environment	8.3.4.2- 45
8.3.4.2.4.1.4 Activity 1.10.4.1.4: Dissolution of phases in the waste package environment	8.3.4.2- 46
8.3.4.2.4.1.5 Activity 1.10.4.1.5: Effects of radiation on water chemistry	8.3.4.2- 47
8.3.4.2.4.1.6 Activity 1.10.4.1.6: Effects of container and borehole liner corrosion products on water chemistry	8.3.4.2- 48
8.3.4.2.4.1.7 Activity 1.10.4.1.7: Numerical analysis and modeling of rock-water interaction	8.3.4.2- 49
8.3.4.2.4.2 Study 1.10.4.2: Hydrologic properties of waste package environment	8.3.4.2- 51
8.3.4.2.4.2.1 Activity 1.10.4.2.1: Single-phase fluid system properties	8.3.4.2- 52
8.3.4.2.4.2.2 Activity 1.10.4.2.2: Two-phase fluid system properties	8.3.4.2- 54
8.3.4.2.4.2.3 Activity 1.10.4.2.3: Numerical analysis of flow and transport in laboratory systems	8.3.4.2- 55
8.3.4.2.4.3 Study 1.10.4.3: Mechanical attributes of the waste package environment	8.3.4.2- 56
8.3.4.2.4.3.1 Activity 1.10.4.3.1: Waste package environment stress field analysis	8.3.4.2- 56
8.3.4.2.4.4 Study 1.10.4.4: Engineered barrier system field tests	8.3.4.2- 57
8.3.4.2.4.4.1 Activity 1.10.4.4.1: Repository horizon near-field hydrologic properties	8.3.4.2- 57
8.3.4.2.4.4.2 Activity 1.10.4.4.2: Repository horizon rock-water interaction	8.3.4.2- 58

TABLE OF CONTENTS (continued)

	Page
8.3.4.2.4.4.3 Activity 1.10.4.4.3: Numerical analysis of fluid flow and transport in the repository horizon near-field environment	8.3.4.2- 61
8.3.4.2.4.5 Application of results.	8.3.4.2- 64
8.3.4.2.5 Schedule for postclosure waste package characteristics	8.3.4.2- 65
8.3.4.3 Issue resolution strategy for Issue 2.6: Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the preclosure design criteria of 10 CFR 60.135 and (b) provide information for the resolution of the performance issues?	8.3.4.3- 1
8.3.4.3.1 Information Need 2.6.1: Design information needed to comply with preclosure criteria from 10 CFR 60.135(b) for materials, handling, and identification of waste packages	8.3.4.3- 5
8.3.4.3.1.1 Application of results	8.3.4.3- 7
8.3.4.3.2 Information Need 2.6.2: Design information needed to comply with preclosure criteria from 10 CFR 60.135(c) for waste forms	8.3.4.3- 7
8.3.4.3.2.1 Application of results	8.3.4.3- 8
8.3.4.3.3 Information Need 2.6.3: Waste acceptance specifications	8.3.4.3- 8
8.3.4.3.3.1 Application of results	8.3.4.3- 9
8.3.4.3.4 Schedule for preclosure waste package characteristics	8.3.4.3- 9
8.3.4.4 Issue resolution strategy for Issue 4.3: Are the waste package production technologies adequately established for the resolution of the performance issues?	8.3.4.4- 1
8.3.4.4.1 Information Need 4.3.1: Identification and evaluation of production technologies for fabrication, closure, and inspection of the waste package	8.3.4.4- 3
8.3.4.4.1.1 Design Activity 4.3.1.1: Waste package fabrication process development	8.3.4.4- 3
8.3.4.4.1.2 Design Activity 4.3.1.2: Waste package closure process development	8.3.4.4- 4
8.3.4.4.1.3 Design Activity 4.3.1.3: Waste package closure inspection process development	8.3.4.4- 5
8.3.4.4.1.4 Application of results	8.3.4.4- 5
8.3.4.4.2 Schedule for waste package production technologies	8.3.4.4- 6

LIST OF FIGURES

VOLUME VI

Figure	Title	Page
8.3.2.1-1	Relationships between design and performance related issues used directly in performance allocation	8.3.2.1- 2
8.3.2.1-2	Schematic diagram of the input to and output from a design or performance issue	8.3.2.1- 4
8.3.2.2-1a	General approach for Issue 1.11 (configuration of underground facilities--postclosure)	8.3.2.2- 2
8.3.2.2-1b	Legend for Figure 8.3.2.2-1a	8.3.2.2- 3
8.3.2.2-2	Relationship between subsumed information needs and issue functions and parameters for Issue 1.11, configuration of underground facilities (postclosure)	8.3.2.2- 22
8.3.2.2-3	Schedule information for Issue 1.11 (configuration of underground facilities)	8.3.2.2- 79
8.3.2.3-1	Relationship of Issue 2.7 (repository design criteria for radiological safety) to other issues and the site characterization program	8.3.2.3- 2
8.3.2.3-2a	Logic diagram for Issue 2.7 (repository design criteria for radiological safety)	8.3.2.3- 13
8.3.2.3-2b	Legend for Figure 8.3.2.3-2a	8.3.2.3- 14
8.3.2.3-3	Schedule information for activities in Issue 2.7 (repository design criteria for radiological safety)	8.3.2.3- 46
8.3.2.4-1a	Logic diagram for Issue 4.2 (nonradiological health and safety)	8.3.2.4- 2
8.3.2.4-1b	Legend for Figure 8.3.2.4-1a	8.3.2.4- 3
8.3.2.4-2	Schedule information for design activities in Issue 4.2 (nonradiological health and safety)	8.3.2.4- 32
8.3.2.5-1a	Logic diagram for Issue 4.4 (preclosure design and technical feasibility)	8.3.2.5- 2

LIST OF FIGURES (continued)

Figure	Title	Page
8.3.2.5-1b	Legend for Figure 8.3.2.5-1a	8.3.2.5- 3
8.3.2.5-2	Hierarchical relationships of requirements documents	8.3.2.5- 48
8.3.2.5-3	Schedule information for information needs in Issue 4.4 (preclosure design and technical feasibility)	8.3.2.5- 98
8.3.3.1-1	Anticipated sequencing of sealing activities	8.3.3.1- 2
8.3.3.2-1a	Logic diagram for Issue 1.12 (seal characteristics)	8.3.3.2- 4
8.3.3.2-1b	Legend for Figure 8.3.3.2-1a	8.3.3.2- 5
8.3.3.2-2	Sealing subsystems, seal locations, and seal components	8.3.3.2- 8
8.3.3.2-3	Schematic diagram of performance goals and relationship to anticipated and unanticipated episodic flows for sealing	8.3.3.2- 23
8.3.3.2-4	Comparison of borehole plug test with experimental data for fractured basalt	8.3.3.2- 59
8.3.3.2-5	Schedule information for studies and design activities in Issue 1.12 (seal characteristics)	8.3.3.2- 71
8.3.4-1	Waste package postclosure compliance strategy	8.3.4- 2
8.3.4.1-1	Relationships between design- and performance-related issues used directly in performance allocation	8.3.4.1- 2
8.3.4.2-1a	Logic diagram for the resolution of Issue 1.10 (postclosure waste package characteristics)	8.3.4.2- 2
8.3.4.2-1b	Legend for Figure 8.3.4.2-1a	8.3.4.2- 3
8.3.4.2-2	Model hierarchy for Issue 1.10 (waste package characteristics--postclosure)	8.3.4.2- 5
8.3.4.2-3	Schedule information for the information needs and studies for Issue 1.10 (waste package characteristics--postclosure)	8.3.4.2- 66

LIST OF FIGURES (continued)

Figure	Title	Page
8.3.4.3-1a	Logic diagram for the resolution of Issue 2.6 (waste package characteristics--preclosure) . . .	8.3.4.3- 3
8.3.4.3-1b	Legend for Figure 8.3.4.3-1a	8.3.4.3- 4
8.3.4.3-2	Schedule information for Issue 2.6 (waste package characteristics--preclosure)	8.3.4.3- 10
8.3.4.4-1	Logic diagram for the resolution of Issue 4.3 (waste package production technologies)	8.3.4.4- 2
8.3.4.4-2	Schedule information for design activities in Issue 4.2 (waste package production technologies)	8.3.4.4- 7

LIST OF TABLES

VOLUME VI

Table	Title	Page
8.3.2.1-1	Studies or activities for coupled interaction tests	8.3.2.1- 15
8.3.2.1-2	Nevada Nuclear Waste Storage Investigations Project design tradeoff analyses	8.3.2.1- 20
8.3.2.2-1	Performance measures, goals, and needed confidence for selecting orientation, geometry, layout and depth of underground facility (postclosure design function 1)	8.3.2.2- 8
8.3.2.2-2	Performance measures, goals, and needed confidences for limiting water usage and potential chemical changes (postclosure design function 2)	8.3.2.2- 13
8.3.2.2-3	Performance measures, goals, and needed confidences for limiting potential for excavation-induced changes in rock mass permeability (postclosure design function 3)	8.3.2.2- 15
8.3.2.2-4	Performance measures, goals, and needed confidences for designing thermal loading taking into account performance objectives and thermomechanical response of host rock (postclosure design function 4)	8.3.2.2- 17
8.3.2.2-5	Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)	8.3.2.2- 25
8.3.2.2-6	Relationship of Information Need 1.11.3 products to the processes associated with function 1 given in Table 8.3.2.2-1	8.3.2.2- 45
8.3.2.2-7	Parameters and information required to satisfy Information Need 1.11.3	8.3.2.2- 47
8.3.2.2-8	Relationship of Information Need 1.11.4 products to the processes associated with function 2	8.3.2.2- 55
8.3.2.2-9	Parameters and information items required to satisfy Information Need 1.11.4	8.3.2.2- 56

LIST OF TABLES (continued)

Table	Title	Page
8.3.2.2-10	Relationship of Information Need 1.11.5 products to the processes associated with function 3	8.3.2.2- 60
8.3.2.2-11	Parameters and information required to satisfy Information Need 1.11.5	8.3.2.2- 62
8.3.2.2-12	Relationship of Information Need 1.11.6 products to the processes associated with function 4	8.3.2.2- 66
8.3.2.2-13	Analyses and input items required to resolve Information Need 1.11.6	8.3.2.2- 68
8.3.2.2-14	Parameters for thermal and thermomechanical analyses	8.3.2.2- 69
8.3.2.2-15	Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design)	8.3.2.2- 84
8.3.2.3-1	Design criteria for the geologic repository operations area	8.3.2.3- 4
8.3.2.3-2	Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety)	8.3.2.3- 17
8.3.2.3-3	Parameters required for Issue 2.7 (repository design criteria for radiological safety)	8.3.2.3- 30
8.3.2.3-4	Major events and planned completion dates for activities in Issue 2.7 (repository design criteria for radiological safety)	8.3.2.3- 47
8.3.2.4-1	Performance measures, goals, and needed confidences for System Element 1.2.1.1 (access construction) pertinent to Issue 4.2, nonradiological health and safety	8.3.2.4- 8
8.3.2.4-2	Performance measures, goals, and needed confidences for System Element 1.2.1.2 (drift construction) pertinent to Issue 4.2, nonradiological health and safety	8.3.2.4- 12
8.3.2.4-3	Performance measures, goals, and needed confidences for System Element 1.2.1.3 (borehole construction) pertinent to Issue 4.2, nonradiological health and safety	8.3.2.4- 15

LIST OF TABLES (continued)

Table	Title	Page
8.3.2.4-4	Performance measures, goals, and needed confidences for System Element 1.2.1.6 (mining ventilation) pertinent to Issue 4.2, nonradiological health and safety	8.3.2.4- 16
8.3.2.4-5	Performance measures, goals, and needed confidences for System Element 1.2.2.5 (retrieval) pertinent to Issue 4.2, nonradiological health and safety	8.3.2.4- 17
8.3.2.4-6	Performance measures, goals, and needed confidences for System Element 1.2.2.7 (waste ventilation) pertinent to Issue 4.2, nonradiological health and safety	8.3.2.4- 19
8.3.2.4-7	Performance measures, goals, and needed confidences for System Element 1.2.4.1 (underground closure) pertinent to Issue 4.2, nonradiological health and safety	8.3.2.4- 20
8.3.2.4-8	Performance measures, goals, and needed confidences for System Element 1.2.5.6 (maintenance) pertinent to Issue 4.2, nonradiological health and safety	8.3.2.4- 21
8.3.2.4-9	Performance measures, goals, and needed confidences for System Element 1.2.5.9.2 (nonradiological monitoring) pertinent to Issue 4.2, nonradiological health and safety . . .	8.3.2.4- 22
8.3.2.4-10	Major events and planned completion dates for activities in Issue 4.2 (nonradiological health and safety)	8.3.2.4- 33
8.3.2.5-1	Preliminary performance allocation for System Element 1.1.1, surface	8.3.2.5- 7
8.3.2.5-2	Preliminary performance allocation for System Element 1.1.2, subsurface	8.3.2.5- 13
8.3.2.5-3	Preliminary performance allocation for System Element 1.2.1.1, access construction . . .	8.3.2.5- 18
8.3.2.5-4	Preliminary performance allocation for System Element 1.2.1.2, drift construction	8.3.2.5- 22

LIST OF TABLES (continued)

Table	Title	Page
8.3.2.5-5	Preliminary performance allocation for System Element 1.2.1.3, borehole construction	8.3.2.5- 24
8.3.2.5-6	Preliminary performance allocation for System Element 1.2.1.4, rock handling	8.3.2.5- 25
8.3.2.5-7	Preliminary performance allocation for System Element 1.2.1.5, water removal	8.3.2.5- 26
8.3.2.5-8	Preliminary performance allocation for System Element 1.2.1.6, mining ventilation	8.3.2.5- 27
8.3.2.5-9	Preliminary performance allocation for System Element 1.2.2.4, emplacement	8.3.2.5- 29
8.3.2.5-10	Preliminary performance allocation for System Element 1.2.2.5, retrieval	8.3.2.5- 30
8.3.2.5-11	Preliminary performance allocation for System Element 1.2.2.7, waste handling ventilation	8.3.2.5- 31
8.3.2.5-12	Preliminary performance allocation for System Element 1.2.4.1, underground closure	8.3.2.5- 32
8.3.2.5-13	System elements for the Yucca Mountain mined geologic disposal system addressed by each information need	8.3.2.5- 33
8.3.2.5-14	Organization of repository design requirements	8.3.2.5- 50
8.3.2.5-15	Preclosure design analyses	8.3.2.5- 63
8.3.2.5-16	List of planned analyses	8.3.2.5- 76
8.3.2.5-17	Issues and programs that use design analyses results	8.3.2.5- 84
8.3.2.5-18	Major events and planned completion dates for information needs in Issue 4.4 (preclosure design and technical feasibility)	8.3.2.5-100
8.3.3.2-1	Sealing components and associated functions, processes, material properties, performance measures, and goals	8.3.3.2- 9

LIST OF TABLES (continued)

Table	Title	Page
8.3.3.2-2	General design constraints passed to Issue 1.11, configuration of underground facilities (postclosure), for major repository features from sealing program	8.3.3.2- 13
8.3.3.2-3	Hydrologic-related site parameters needed to support resoltuion of Issue 1.12 (seal characteristics)	8.3.3.2- 16
8.3.3.2-4	Miscellaneous information needed to support resolution of Issue 1.12	8.3.3.2- 19
8.3.3.2-5	Design-basis performance goals for the sealing subsystem	8.3.3.2- 28
8.3.3.2-6	Potentially important material properties of concern for sealing components	8.3.3.2- 38
8.3.3.2-7	Site properties needed for Issue 1.12 (seal characteristics)	8.3.3.2- 43
8.3.3.2-8	Seal material and emplacement environment properties needed	8.3.3.2- 46
8.3.3.2-9a	Emplacement concerns for the preferred sealing options	8.3.3.2- 48
8.3.3.2-9b	Emplacement concerns for the secondary sealing options	8.3.3.2- 52
8.3.3.2-10	Major events and planned completion dates for studies and design activities in Issue 1.12 (seal characteristics)	8.3.3.2- 72
8.3.4-1	Waste package postclosure compliance strategy	8.3.4- 2
8.3.4.1-1	Relationship between design- and performance-related issues used directly in performance allocation	8.3.4.1- 2
8.3.4.2-1	Model hierarchy and model inputs for Issue 1.10 (waste package characteristics--postclosure)	8.3.4.2- 6
8.3.4.2-2	Performance measures and goals for Issue 1.10 (waste package characteristics--postclosure)	8.3.4.2- 9

LIST OF TABLES (continued)

Table	Title	Page
8.3.4.2-3	Performance parameters and goals for Issue 1.10 (waste package characteristics--postclosure)	8.3.4.2- 10
8.3.4.2-4	Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure)	8.3.4.2- 11
8.3.4.2-5	Major events and planned completion dates for information needs and studies in Issue 1.10 (postclosure waste package characteristics)	8.3.4.2- 68
8.3.4.3-1	Performance allocation for Issue 2.6 (waste package characteristics--preclosure)	8.3.4.3- 5
8.3.4.3-2	Major events and planned completion dates for Issue 2.6 (preclosure waste package characteristics)	8.3.4.3- 11
8.3.4.4-1	Major events and planned completion dates for design activities in Issue 4.3 (waste package production technologies)	8.3.4.4- 8

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)



Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.2, Repository Program

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.2 REPOSITORY PROGRAM

This section summarizes the repository program and provides an overview of the research, development, and engineering activities required to ensure that the repository is capable of satisfying applicable technical criteria. Issue resolution strategies for Issue 1.11 (configuration of underground facilities), Issue 2.7 (repository design criteria for radiological safety), Issue 4.2 (nonradiological health and safety), and Issue 4.4 (preclosure design and technical feasibility) are presented in this section. Plans for the future work are based in large part on the current designs and the results of analyses completed to date; the current designs and analyses are presented in Chapter 6 (conceptual design of a repository).

The schedule information provided in this section includes the sequencing, interrelationships, and durations of the design activities and should be regarded as a snapshot in time. Section 8.5 presents the major milestones, decision points, and summary schedule information for the repository program.

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.2.1, Repository Overview

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.2.1 Overview of repository program

The primary purpose of Section 8.3.2 is to describe the plans for completing the repository design work as it progresses through the sequence of design phases leading to construction of the repository. Those aspects of the design concerned specifically with site characteristics are discussed fully in this document. Other aspects, such as certain equipment designs and operations plan development (and supporting analyses and demonstrations), that do not rely heavily on site data are not discussed in detail. Rather, only enough information on these aspects is provided to define their role in issue resolution. A complete treatment of such aspects will be provided in the repository design plan (RDP). Thus, the RDP will describe fully all plans for completing the repository design work as it progresses through the sequence of design phases leading to construction of the repository, including work that relies directly on site data and that that does not. For example, substantially more detail will be provided in the RDP than in the SCP regarding the equipment development program and the nonsite-related aspects of radiological safety.

The plans described here in Section 8.3.2 are organized under four repository design issues that are part of the issues hierarchy. (Sections 8.1 and 8.2 list the issues and describe the general strategy and methodology for resolving them). Plans for completing the work necessary to resolve these four issues are discussed in the following four subsections:

Subsection	Issue	Issue short title
8.3.2.2	1.11	Configuration of underground facilities (postclosure)
8.3.2.3	2.7	Repository design criteria for radiological safety
8.3.2.4	4.2	Nonradiological health and safety
8.3.2.5	4.4	Preclosure design and technical feasibility

The work planned to resolve the four design issues is interrelated. Further, work described under several issues in other subsections of Section 8.3 is also tied closely to the work planned to be done under the four issues discussed here. Figure 8.3.2.1-1 graphically depicts the relationships between design-related issues by showing pathways along which information will be passed between the issues. Details about the information passed between issues are presented in the SCP sections in which the specific issues are discussed. As seen in the figure, the related issues include some performance issues as well as other design issues.

Numerous requirements and constraints are imposed on the overall repository design (i.e., on the work to be done under the repository design issues) because of the necessity for the repository to meet certain preclosure and postclosure performance requirements (i.e., by performance issues found in Section 8.3.5). For example, from the preclosure perspective, the repository must be designed, constructed, and operated in a manner that (1) preserves the option to retrieve waste until the license amendment for permanent closure is granted and (2) meets the requirements of radiological health and safety. Performance requirements involving retrievability (Section 8.3.5.2) and radiological health and safety (Sections 8.3.5.3

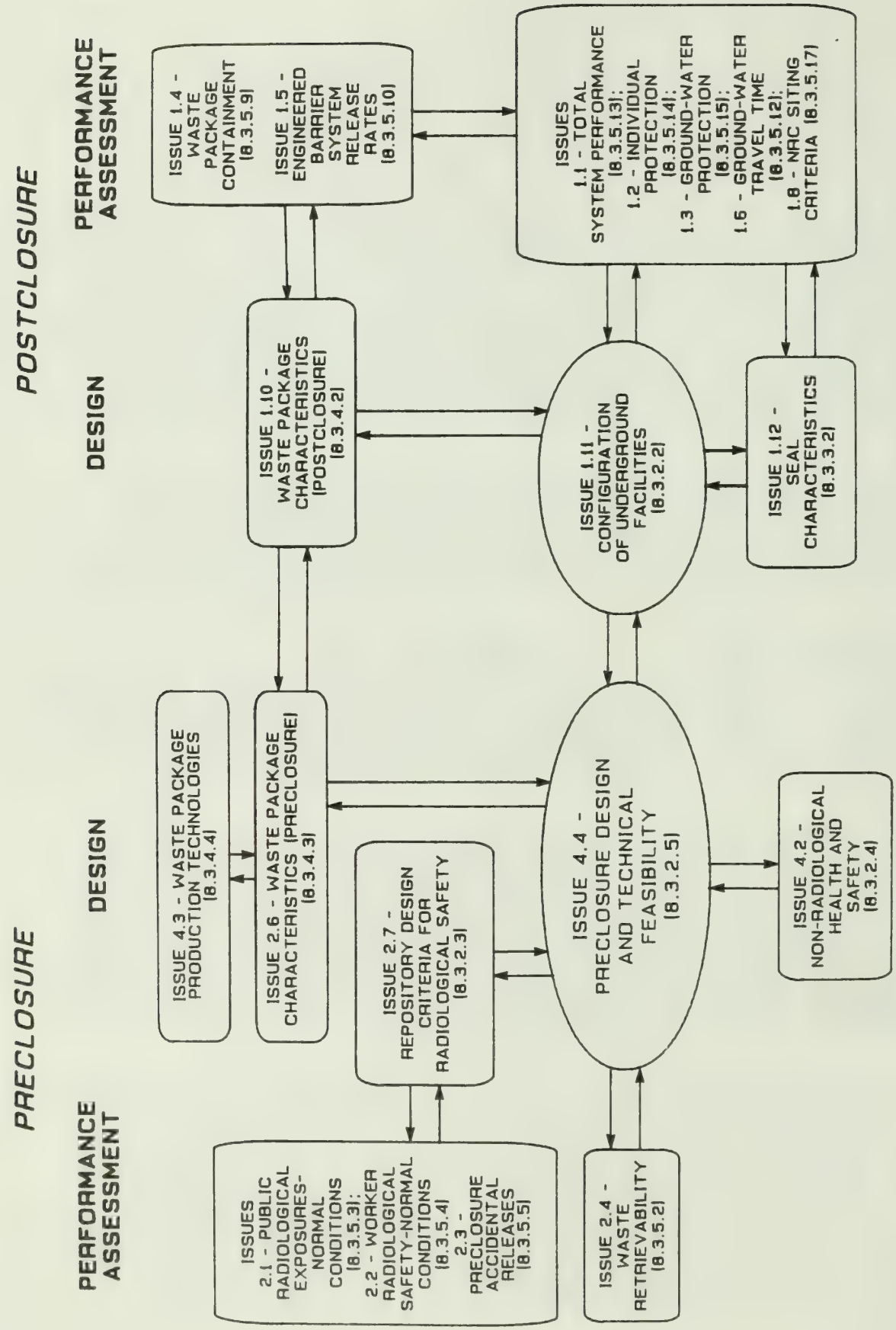


Figure 8.3.2.1-1. Relationships between design and performance related issues used directly in performance allocation

through 8.3.5.5) are developed in the preclosure subsections of Section 8.3.5 (performance assessment program) and communicated to the repository design issues. Also, for preclosure operations, the repository facilities must be designed to handle the waste and waste packages and to accommodate the waste package design requirements and constraints described under the waste package issues in Section 8.3.4 (waste package program). The requirements and constraints placed on the design issues by performance issues (and even other design issues) are usually accompanied by requests of the design to prepare certain specific products, the primary use of which is to help resolve the issue specifying the requirements. The output of many of the issues identified in Figure 8.3.2.1-1 consists of items like design activity and evaluation reports, equipment demonstration reports, design drawings and supporting analyses, operations plans, etc. These are often called products in the issues under which they are developed. These products may be requested by other issues (perhaps along with site parameters) as input to perform required tasks. The products are called "input items" by the requesting issue, to distinguish them from the products of that same issue (Figure 8.3.2.1-2). The input items needed by an issue are generally listed along with the site parameters in the appropriate tables within that issue.

From the postclosure perspective, the repository facilities must be designed to accommodate the performance requirements and constraints developed and described under the waste package, engineered barrier system, and total system performance issues in Section 8.3.5. In addition, the repository design must accommodate the emplacement of seals for the shafts, ramps, exploratory boreholes, and underground facilities, as described under Issue 1.12 in Section 8.3.3 (seal program).

In addition to the general relationships between issues indicated by the above discussion, there is an additional division of responsibility among the design-related issues shown in Figure 8.3.2.1-1. The following example concerning the topic of mined openings will serve to describe this division of responsibility. Issue 4.2 (Section 8.3.2.4) is concerned with the stability of mined openings as it relates to the nonradiological health and safety of workers. Issue 2.4 (Section 8.3.5.2) is concerned with maintaining stable openings for the entire period of retrievability in order to preserve access to the waste. Radiological safety issues 2.3 and 2.7 (Sections 8.3.5.5 and 8.3.2.3) are concerned with opening stability as it relates to potential initiating events for release of radionuclides into the environment of the workers and public. Issue 1.11 (Section 8.3.2.2) is concerned with the stability of those same openings after closure, because their long-term instability might create preferred pathways for water migration toward waste packages and compromise containment of the waste within the waste package. Finally, Issue 4.4 (Section 8.3.2.5) is concerned with providing stable mined openings large enough for moving equipment, personnel, materials, and ventilation air. With this spectrum of interest in the topic, it would be easy to perform duplicate work in resolving the different issues. To avoid such duplication, a careful division of responsibility between issues has been adopted. Issue 4.4 has been assigned the responsibility for the design of mined openings and for conducting the necessary stability analyses in support of the design. Other issues will impose design requirements or constraints upon Issue 4.4 pertinent to their needs, and will receive the design and other input items (e.g., supporting analyses) back from Issue 4.4.

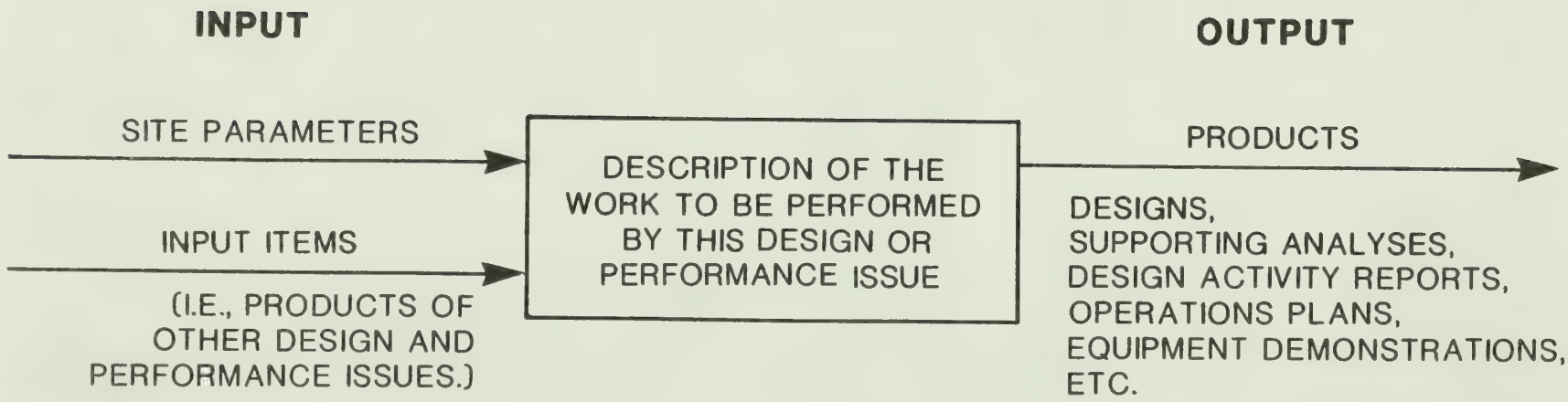


Figure 8.3.2.1-2. Schematic diagram of the input to and output from a design or performance issue.

Under each issue the design and the supporting analyses will be evaluated to judge whether the requirements for mined opening stability have been satisfied.

In a like manner, where Issue 4.4 shares similar design requirements with another issue on a particular facet of the repository design, Issue 4.4 has been assigned the responsibility for developing the design and providing the other three parts of the four-part design package (namely, the operating plan, supporting analyses, and any necessary demonstrations). The related issue(s) provide requirements and constraints (and requests for other input items) to Issue 4.4 and receive the design package in return from Issue 4.4. The logic diagram for Issue 4.4 illustrates these relationships. With this division of responsibility, Issue 4.4 is the issue that requests most of the data on site characteristics. This division of responsibility is also indicated in the logic diagrams and the supporting text and tables that discuss the design-related issues shown in Figure 8.3.2.1-1.

Figure 8.3.2.1-1 illustrates the interfaces by which design and performance issues exchange information. As the figure caption indicates, the specific design and performance issues portrayed in the figure are those that were used directly in the performance allocation process. Two general aspects of the figure are worth emphasizing. First, the figure was prepared primarily to illustrate the exchange of design criteria and design products between design issues. Accordingly, the figure does not provide specific detail about how the performance issues exchange information. The second general aspect of the figure worth noting is that not all of the design and performance issues in the issues hierarchy are portrayed on the figure.

Three of the issues absent from the figure are concerned with the higher level findings required by 10 CFR Part 960. These are Issues 1.9 (higher level findings--postclosure, Section 8.3.5.18), 2.5 (higher level findings--preclosure radiological safety, Section 8.3.5.6), and 4.1 (higher level findings--ease and cost of construction, Section 8.3.5.7). The primary reason for excluding higher level finding issues from the figure is that, at the current time, the resolution strategies for these issues do not require any data other than that requested for the resolution of the other design or performance issues. This is not expected to change, but if it should, an SCP progress report would be the vehicle to convey changes in the interrelationship diagram as well as changes to the preliminary performance allocation.

Issue 1.7 (performance confirmation, Section 8.3.5.16) is also absent from the figure because it is not considered possible at this time to develop a detailed, site-specific issue resolution strategy for performance confirmation. As site characterization progresses, however, the performance allocation for the Yucca Mountain site may change in response to a defined issue resolution strategy for performance confirmation. This information would also be reported in SCP progress reports.

The conceptual design of the repository is presented in Chapter 6 (and described in detail in the SCP Conceptual Design Report (SCP-CDR)) (SNL, 1987), along with extensive discussions that synopsize the analyses completed in support of the conceptual design. In Section 6.4 of this document, the analyses are discussed in the context of resolving the design issues and design-related performance issues (i.e., it provides a status of the work

done to resolve the issues). Section 6.4 also provides background information for the additional work necessary to complete resolution of issues, as described in various subsections of Section 8.3. Site information used in the conceptual design and supporting analyses is reported in Chapters 1 through 5 of this SCP. (Those chapters also contain data that in some instances supersedes or postdates data used in the SCP-CDR.) Additional site data needed to support the design efforts will be acquired under the site program described previously in Section 8.3.1. Figure 8.3.2.1-1, however, does not show any ties to the site program; these ties were omitted in the interest of clarity in showing the ties between the design-related issues. The issue resolution logic diagrams, presented in each 8.3 issue-related section, however, do show the specific calls for data from the site program.

Before proceeding to the four design issues to be discussed in this section, the repository design phases are described, followed by a discussion of four specific subject areas:

1. Host rock environment (Section 8.3.2.1.1).
2. Coupled interaction tests (Section 8.3.2.1.2).
3. Design optimization activities and tests (Section 8.3.2.1.3).
4. Repository modeling (Section 8.3.2.1.4).

The design of the systems, components, excavations, structures, and barriers necessary to establish and demonstrate compliance with the performance objectives of 10 CFR Part 60 should be substantially completed at the time the license application is submitted to the NRC. To accomplish this, the DOE has divided the design of the repository as follows (DOE, 1985b):

1. Conceptual design phase.
   a. Conceptual design for the site characterization plan.
   b. Advanced conceptual design.

2. Title I and II design.
   a. License application design.
   b. Final procurement and construction design.

Design phases

Conceptual design for the site characterization plan

The SCP conceptual design phase is complete. This design phase concentrated on the surface and underground system, structure, and component designs that require site characterization data and provide the information to ensure that data-gathering plans relative to design will be adequate. Known site-specific data have been incorporated to help identify additional data needs, and sufficient design detail was developed to ensure that site data needs are identified and site-specific licensing issues related to site characterization have been identified. In addition, where available, data accuracy requirements have been identified. This design has been extensively referenced in Chapter 6.

Advanced conceptual design

The advanced conceptual design phase will be used to explore design alternatives and will firmly fix and refine the design criteria and concepts to be used in later design efforts. The project feasibility will be demonstrated, the life-cycle cost estimated, preliminary drawings prepared, and a construction schedule developed as required in DOE Order 4700.1 (DOE, 1987). The design will be developed with Project and configuration control as required by the DOE procedures for major system acquisitions and will comply with the configuration control program requirements of 10 CFR Part 50, Appendix B. This design will also identify any remaining design-related licensing issues not defined in the SCP conceptual design.

During the advanced conceptual design phase, the DOE objective is to develop appropriate solutions to all identified design-related licensing issues through consultation with the NRC as established by the Procedural Agreement between the U.S. Nuclear Regulatory Commission and the DOE identifying guiding principles for interface during site investigation and site characterization (NRC/DOE, 1983).

License application design

The license application (LA) portion of the Title I and Title II design phases will start after the completion of the advanced conceptual design (ACD) report; it will conclude with the development of an LA design report. The LA design phase will support the resolution of design and licensing issues identified and assessed in earlier design phases and will develop the design of the items necessary to demonstrate compliance with the design requirements and performance objectives of 10 CFR Part 60. Therefore, sufficient design information will be developed during the LA design phase to meet the requirements of 10 CFR 60.21 for the license application. Design requirements resulting from detailed safety and reliability analyses will be fully integrated into the LA design and will form the basis for information required in the safety analysis report. The design of nonlicensing-related ancillary systems will be developed only to the extent necessary to ensure their proper function and adequate cost and schedule planning.

Final procurement and construction design

This portion of the Title I and II phases will develop the final (working) drawings and specifications for procurement and construction. The completion of this design phase will match the completion of the Title II design effort for the entire repository. This design phase will emphasize the completion of the design of ancillary support items, final design refinement for the items necessary to demonstrate compliance with the design criteria and performance objectives of 10 CFR Part 60, the development of construction bid packages for all systems, and the development of final construction and procurement schedules.

The DOE is currently initiating an effort to combine several program activities under a single System Engineering Development and Management (SEDM) contractor. In this approach, the SEDM contractor would prepare the ACD. Detailed plans for the design sequence under the SEDM contractor have not been developed. It is expected, however, that the design work to be

accomplished under the plan described in this SCP will be the same, in total, as that performed under an SEDM contractor.

8.3.2.1.1 Verification or measurement of host-rock environment

Information from site explorations before the site characterization phase have permitted an understanding to be developed of the host-rock environment within which the underground facilities will be constructed. This understanding is described in detail in Chapters 1 through 7, in particular, (1) the geology, geophysics, seismicity, and tectonics of the site and surrounding area are described in Chapter 1 (geology); (2) the mechanical and thermal properties of the rock and soils at the site are described in Chapter 2 (geoengineering); (3) the hydrologic conditions and properties are described in Chapter 3 (geohydrology); and (4) the geochemical conditions and properties are described in Chapter 4 (geochemistry).

Plans to verify the current understanding and acquire necessary additional information about the host-rock environment are described here in Chapter 8. Section 8.3.1 (site program) describes the site investigations (studies, tests, and analyses) that will be conducted to acquire the additional site data. For convenience, the descriptions of the site investigations are grouped according to topical areas (e.g., geology program, rock characteristics program, and hydrology program).

Plans for completing the design of the repository facilities, the seals, and the waste packages are found in Section 8.3.2 (repository program), 8.3.3 (seal program), and 8.3.4 (waste package program), respectively. Similarly, plans for conducting assessments of the performance of the total mined geologic disposal system (MGDS) and the appropriate components are described in Section 8.3.5 (performance assessment program). These design and performance assessment plans are organized in accordance with the issues hierarchy described in Section 8.2. The site data needed to resolve each design and performance issue is defined within the discussion of the plans for resolution of the respective issue. The need for site data is then transmitted to the appropriate site program where the detailed plans for acquiring the data are described. No plans for acquiring site data are described within the design or performance issues themselves. These issues simply describe how the site data and other items of information will be used to resolve the issue. Correspondingly, only site data that are required to resolve a design or performance issue, or are needed to support another characterization program are acquired under the site program.

It is within this context that the topic of this section, verification or measurement of the host-rock environment, is addressed for design issues. The site data identified in the data chapters noted previously have been used to develop conceptual models of the host-rock environment within which the repository facilities will be constructed. These conceptual models and their influence on the conceptual design of the repository facilities are described in Chapter 6 (conceptual design of the repository). This conceptual design, the existing site data, the conceptual models, and the understanding they convey, taken together with the regulatory and other requirements upon the MGDS, form the basis for the plans for resolution of the design issues.

The role of the host-rock environment in the process can be divided into three phases or conditions: (1) pre-waste-emplacement environment (the host-rock conditions in the pre-excavation, pristine, in situ state); (2) post-subsurface-excavation environment (e.g., the conditions of rock stress and deformation as a result of excavation); and (3) post-waste-emplacement environment (e.g., the conditions resulting from the combined effects of excavation and added heat from the emplaced waste). In the subsections that follow, topics of concern during each of the phases will be identified, and the reader will be directed to those design issues (and their respective SCP subsections) in which the topics are addressed. In addition, the specific site program will be identified from which site data are requested in order to resolve host-rock environment questions in the respective design issues.

8.3.2.1.1.1 Pre-waste-emplacement environment

Current knowledge of the pre-waste-emplacement geologic, geotechnical, hydrologic, and geochemical environment of the host rock has been used to develop models or descriptions of characteristics of the site in its pristine state. As noted in the previous section, the current description of the host-rock environment, together with some descriptive models, is found in Chapters 1 through 4. These data and models have assisted in identifying the site location, repository elevation, usable area, boundary conditions, and predicted response of the host rock to excavation and thermally induced loads. Further, during the site exploration phase of the characterization program, conceptual models were developed to assist in repository conceptual design as presented in Chapter 6 (preliminary performance assessments were also developed--refer to Section 8.3.5).

To conduct the design analyses and activities necessary to resolve the four design issues included in this section (8.3.2, repository program), additional site data pertaining to pre-waste-emplacement and preexcavation conditions are needed to

1. Confirm the three-dimensional model of the thermal and mechanical stratigraphy and structure of Yucca Mountain.

2. Develop a three-dimensional model for estimating the in situ stress state at Yucca Mountain.

3. Develop a three-dimensional model of the in situ temperature field at Yucca Mountain.

4. Evaluate mineability, fragmentation characteristics, dust characteristics, and potential excavation methods of the host rock.

5. Design and evaluate a ground support system for the underground facility and egresses.

6. Determine rock-mass deformation and estimate strength properties.

7. Determine the effects of confining pressure upon intact rock strength and fracture slip such that a strength and slip criterion, respectively, may be developed.

8. Determine the effects of time (the strain rate effect) upon intact rock strength.

9. Determine the sample size effect upon intact rock strength.

10. Determine the sensitivity of potential designs of system elements to material properties and their variability.

11. Provide pretest support of all mechanical, thermal, and thermo-mechanical experiments planned for the exploratory shaft facility.

12. Design a ventilation system for the repository facilities.

13. Evaluate the effects of radon gas emanation.

14. Evaluate the effect of structural features for standoff and special construction considerations.

15. Evaluate the potential for water inflow into the underground facilities.

Site data required to conduct these design analyses and activities will be acquired under the following specific site programs:

SCP section	Site program
8.3.1.4	Rock characteristics
8.3.1.6	Erosion
8.3.1.14	Surface characteristics
8.3.1.15	Thermal and mechanical properties
8.3.1.16	Preclosure hydrology

Further, to resolve Issue 4.4 (preclosure design and technical feasibility), additional site data are needed to

1. Validate predictive equations of ground motion at any point in the target horizon.

2. Validate methodology for predicting seismic hazards due to natural earthquakes for ground motion and surface rupture.

3. Determine fault activities at the site including total displacements, displacement rates, evidence of surface rupture, type, and orientation and age of recent activity of the faults in the site area.

4. Determine the attenuation of ground motion with depth (both for acceleration and frequency) as it applies to surface and subsurface facility design.

5. Determine the effects of wave propagation, amplitude, and direction upon surface and subsurface facility design.

Site data required to resolve these seismotectonic design questions will be acquired under the tectonics programs described in Sections 8.3.1.8 and 8.3.1.17.

8.3.2.1.1.2 Post-subsurface-excavation environment

The post-subsurface-excavation geologic and geotechnical environment considers the host-rock environment that reflects, for example, rock stress as a result of rock excavation. Models conceptualized and developed from the standpoint of pre-waste-emplacement, including material response, boundary conditions, and usable area, will be confirmed or modified to assist in resolving the issues identified previously. Certain of the analyses and tests identified for the post-subsurface-excavation condition are meant to continue through development and monitoring programs during the post-waste-emplacement phase (Section 8.3.2.1.1.3) of repository development in order to supplement or confirm earlier concepts.

To conduct the design analyses and activities necessary to resolve the four design issues included in this section (8.3.2, repository program), additional site data pertaining to post-subsurface-excavation conditions are needed to

1. Validate models that are intended to predict the response of the fractured rock mass to excavation loads.

2. Assess the state of stress and deformation at the emplacement borehole scale, drift scale, and repository scale as a result of excavation.

3. Assess the potential impact of rock mass creep upon state of stress and deformations around opening.

4. Evaluate potential excavation methods based on application of candidate methods during the underground exploration program.

5. Evaluate the planned ground support methods based on application of candidate methods to underground openings in the exploratory shaft facility.

6. Evaluate the mechanical response of the rock mass.

Site data required to conduct these design analyses and activities will also be acquired under the following specific site programs:

SCP section	SCP program
8.3.1.4	Rock characteristics
8.3.1.6	Erosion
8.3.1.14	Surface characteristics
8.3.1.15	Thermal and mechanical properties
8.3.1.16	Preclosure hydrology

8.3.2.1.1.3 Post-waste-emplacement environment

The post-waste-emplacement geologic and geotechnical environment considers the host-rock environment that reflects, for example, the combined effects of excavation and heat (from heat-generating waste). For this condition certain of the analyses and tests identified in Sections 8.3.2.1.1.1 (pre-waste-emplacement environment) and 8.3.2.1.1.2 (post-subsurface-excavation environment) are meant to continue through development and monitoring programs during this phase of repository development in order to supplement or confirm earlier results.

To conduct the design analyses and activities necessary to resolve the four design issues included in this section (8.3.2, repository program) and to resolve Issue 2.4 (waste retrievability, Section 8.3.5.2), additional site data pertaining to post-waste-emplacement conditions are needed to

1. Validate models that are intended to predict the response of the fractured rock mass to excavation and thermal loads.

2. Assess the temperature distribution as a function of time and position as a result of thermal loads from heat-generating waste. Analyses will be performed at the emplacement borehole scale, drift scale, and repository scale.

3. Assess the state of stress and deformation as a result of excavation and superposed thermal loads. Response will be predicted at the emplacement borehole scale, the drift scale, and the repository scale.

4. Assess the potential impact of rock creep (time-dependent deformation) upon state of stress and deformations around mined openings.

5. Determine the potential impact of changes in the orientation of the principal stress components upon the intact rock and rock-mass response (deformation and strength behavior).

6. Determine the thermomechanical response of intact samples and representative volumes of the rock mass.

Site data required to conduct these design analyses and activities will also be acquired under the following specific site programs:

SCP section	SCP program
8.3.1.4	Rock characteristics
8.3.1.6	Erosion
8.3.1.14	Surface characteristics
8.3.1.15	Thermal and mechanical properties
8.3.1.16	Preclosure hydrology

8.3.2.1.2 Coupled interaction tests

The design, construction, operation, and assessment of the future performance of a geologic repository must consider five general classes of phenomena. These are thermal, hydrologic, mechanical, chemical, and radiological phenomena. These phenomena may occur individually at a particular time or spatial location without affecting the other phenomena; often, however, the occurrence of one phenomenon may affect the behavior of another phenomenon and, therefore, couple the phenomena and the processes of which they are a part. The number of coupled processes that could exist under the various combinations of coupling the five general classes of phenomena is very large. It is not feasible to perform multivariable tests (i.e., coupled interaction tests) covering all these combinations. Testing will, therefore, occur only if it is relevant to licensing arguments.

Performing multivariable interaction tests is relevant to licensing arguments only if performing those tests is necessary to characterize behavior to show compliance with regulatory criteria. If the investigation of any particular combination of processes does not aid in showing compliance with at least one regulatory criterion, then that investigation is not relevant, and testing to determine the behavior and effects of those coupled processes is not necessary.

Regulatory criteria that must be satisfactorily addressed to receive a construction authorization are addressed within the issues hierarchy incorporated into this document (Section 8.2). Strategies to resolve all issues within the hierarchy, and thereby determine the level of compliance with the regulatory criteria, are addressed in Section 8.3.5 The approach used to determine the relevance of coupled behavior (as well as uncoupled behavior) follows the fundamental issue resolution strategy presented in Section 8.2 and used throughout Section 8.3.5. As a part of that strategy, those licensing arguments and concomitant tests that involve multivariable (i.e., coupled) effects are defined under the issues as information required to resolve those issues. To determine whether the consequences of certain coupled processes are significant, the performance allocated to the various system components is of major importance. It is inherent within the planning approach for site characterization that prior estimates be made to determine what parameters are important in showing regulatory compliance. These estimates of importance have been based upon previous laboratory and field data, performance analyses, and professional judgment.

From the performance allocation, parameters are derived that must be investigated during site characterization. No distinction within the issues is made among parameters that involve coupled interactions and those that do

not; all are simply information required to resolve the issue using the approach stated under the particular issue. All the requirements for the parameters (whether involving coupled interactions or not), as well as the rationale for determining that the set of parameters are necessary and sufficient to show regulatory compliance, are discussed for each issue. Therefore, this section does not discuss a particular subset of tests (i.e., coupled interaction tests) or how the results of those tests are necessary and sufficient. In other words, the strategy for the approach to coupled interaction tests is to let the individual issues specify the parameters necessary for resolving the issue and for showing compliance with the related regulatory criteria. The investigation of coupled interactions considers them not as a specific subset of data requirements, but merely as part of all the information needed to address the regulatory criteria. The tests (some with multivariable interactions and some without) that meet the parameter requirements are described under the appropriate characterization program.

Although no detailed description of coupled interaction tests is provided here, Table 8.3.2.1-1 shows the title of the study or activity involving investigation of multivariable effects, study or activity designation number, and an indication of the processes that will be investigated within the test or tests. The first three numbers of the study or activity designation number reflect the issue and information need under which the coupled interaction test is described.

Although the identification of which tests are considered as coupled interaction tests is somewhat subjective, Table 8.3.2.1-1 attempts to list all of the tests to be performed during site characterization that have a specific objective of investigating one or more processes that are directly interacting with another process. The tests listed in the table either are designed to test the interactions between two or more processes or to provide information to support evaluation of the effects of interactions between two or more processes. The reader should refer to the specific study or activity descriptions within the SCP, as well as the associated study plans and test procedures, for further details on the tests. There are other tests that have not yet been completely defined that will also investigate coupled interactions. These tests will be described in future SCP progress reports when the scopes of the tests are more completely defined.

Many processes involving multivariable phenomena are expected to be shown to be of secondary importance through analyses of their significance to determining the level of compliance with regulatory criteria. Those analyses must be performed under the individual issues because of the variety of regulatory criteria addressed by the issues and the subsequent variety of approaches used to determine the level of compliance. Like the strategy for dealing with multivariable interaction tests, the approach to multivariable interaction analyses is for each performance and design issue to call for the analyses it needs for its resolution. In this document, therefore, those analyses are described under the issues that call for them.

Table 8.3.2.1-1. Studies or activities for coupled interaction tests

Study or activity designation	Study or activity title	Processes investigated[a]
1.5.2.1.1	Dissolution and leaching of spent fuel (Section 8.3.5.10.2.1.1)	C-R-T
1.5.2.1.2	Oxidation of spent fuel (Section 8.3.5.10.2.1.2)	C-R-T
1.5.2.1.3	Corrosion of Zircaloy (Section 8.3.5.10.2.1.3)	C-H-R-T
1.5.2.1.4	Corrosion of and radionuclide release from other materials in the spent fuel waste form (Section 8.3.5.10.2.1.4)	C-H-R-T
1.5.2.1.5	Evaluation of the inventory and release of carbon-14 from Zircaloy cladding (Section 8.3.5.10.2.1.5)	C-R-T
1.10.4.1.1	Rock-water interaction at elevated temperatures (Section 8.3.4.2.4.1.1)	C-T
1.10.4.1.4	Dissolution of phases in the waste package environment (Section 8.3.4.2.4.1.4)	C-T
1.10.4.1.5	Effects of radiation on water chemistry (Section 8.3.4.2.4.1.5)	C-R-T
1.10.4.1.6	Effects of container and borehole liner corrosion products on water chemistry (Section 8.3.4.2.4.1.6)	C-T
1.10.4.2.1	Single-phase fluid system properties (Section 8.3.4.2.4.2.1)	C-H-T

Table 8.3.2.1-1. Studies or activities for coupled interaction tests (continued)

Study or activity designation	Study or activity title	Processes investigated[a]
1.10.4.2.2	Two-phase fluid system properties (Section 8.3.4.2.4.2.2)	C-H-T
1.10.4.4.1	Repository horizon near-field hydrologic properties (Section 8.3.4.2.4.4.1)	H-M-T
1.10.4.4.2	Repository horizon rock-water interaction (Section 8.3.4.2.4.4.2)	C-H-T
1.12.2.1.1	Detailed property determination of cementitious-based material suitable for a tuffaceous environment (Section 8.3.3.2.2.1.1)	C-H-M-T
8.3.1.2.2.4.1	Intact-fracture test in the exploratory shaft facility	C-H-M
8.3.1.2.2.4.4	Radial-borehole tests in the exploratory shaft facility	H-M
8.3.1.2.2.4.5	Excavation-effects test in the exploratory shaft facility	H-M
8.3.1.2.2.4.8	Hydrochemistry tests in the exploratory shaft facility	C-H
8.3.1.2.2.7.1	Gaseous-phase chemical investigations	C-H
8.3.1.2.2.7.2	Aqueous-phase chemical investigations	C-H
8.3.1.2.3.1.5	Testing at the C-hole sites with conservative tracers	C-H
8.3.1.2.3.1.6	Well testing with conservative tracers throughout the site	C-H

Table 8.3.2.1-1. Studies or activities for coupled interaction tests (continued)

Study or activity designation	Study or activity title	Processes investigated[a]
8.3.1.2.3.1.7	Testing at the C-hole sites with reactive tracers	C-H
8.3.1.2.3.1.8	Well testing with reactive tracers throughout the site	C-H
8.3.1.3.2.2.2	Smectite, zeolite, and glass dehydration and transformation	C-H-T
8.3.1.3.3.2.1	Kinetic studies of zeolite and related framework silicates	C-T
8.3.1.3.4.1.3	Sorption as a function of ground-water composition	C-H
8.3.1.3.5.1.1	Solubility measurements	C-H-R-T
8.3.1.3.5.1.2	Speciation measurements	C-H-R-T
8.3.1.3.6.1.1	Crushed tuff column experiments	C-H
8.3.1.3.6.1.2	Mass transfer kinetics	C-H
8.3.1.3.6.1.3	Unsaturated tuff columns	C-H
8.3.1.3.6.1.4	Fractured tuff column studies	C-H
8.3.1.15.1.3.2	Effects of variable environmental conditions on compressive mechanical properties	H-M-T
8.3.1.15.1.4.2	Effects of variable environmental conditions on mechanical properties of fractures	H-M-T
8.3.1.15.1.6.1	Heater experiment in unit TSw1[b]	H-M-T
8.3.1.15.1.6.2	Canister-scale heater experiment	H-M-R-T
8.3.1.15.1.6.3	Yucca Mountain heated block experiment	H-M-T

Table 8.3.2.1-1. Studies or activities for coupled interaction tests (continued)

Study or activity designation	Study or activity title	Processes investigated[a]
8.3.1.15.1.6.4	Thermal stress measurements	M-T
8.3.1.15.1.6.5	Heated room experiment	M-T

[a]The general classes of processes to be investigated include chemical (C), hydrologic (H), mechanical (M), radiation (R), and thermal (T). No degree of importance or test emphasis is implied by the listed order.

[b]TSw1 is the lithophysal portion of the Topopah Spring Member located above the potential repository horizon. In general tests at the site are in TSw2, the proposed repository horizon, unless otherwise indicated.

8.3.2.1.3 Design improvement activities and tests

Optimization implies improving or refining the design to better meet the goals or objectives of a system for a given set of conditions. This is achieved by defining the project as a system with components that meet specific objectives, appraising the performance of the system, and feeding back the information gained through the evaluation to improve the design and its performance. Successive iterations lead to an optimum design.

As the design changes, only a snapshot of it is available at any time before construction; hence, this document reflects that fact, and only the current design is presented. Improvements to the design will follow. Both the design and its detailing are refined as the design progresses through its various phases. The present design phase is conceptual, which includes the SCP conceptual design that accompanies this SCP and the advanced conceptual design (ACD). Future phases are the license application design, which is required to accompany license application to the NRC; the final procurement and construction design; and design revisions required during construction.

For large projects or systems requiring multiple interactions, the design progresses toward an optimum solution, but does not accomplish it in the mathematical sense. Therefore, the goal of the Yucca Mountain Project is not an optimum design solution, but a design that has been optimized to the point of providing an acceptable solution emphasizing certain characteristics. The desired characteristics or attributes of the system are discussed in the following paragraph.

The repository design and operation must be licensable by the NRC and be safe and cost effective according to the DOE. To facilitate addressing

these overall system requirements, the design should be as simple as possible. Simple designs, the performance and reliability of which can be most readily predicted, will facilitate review and expedite licensing. The system will be described in the systems description document. The current repository design is discussed in Chapter 6. The requirements, by which the system will be evaluated, will be provided in the systems requirement and repository design requirement documents. These repository-specific documents will be useful in assessing the degree to which the desirable attributes are present in the Yucca Mountain mined geologic disposal system.

In arriving at a design with the preceding attributes, many tradeoff analyses will be required. The role of tradeoff analyses is to assess alternatives and provide the technical basis for making decisions that will improve the design and hence, system performance. Such studies are required when two or more design alternatives are considered and the most beneficial one is not obvious. The tradeoff analyses determine which design will be most favorable for meeting the system requirements. For example, technical feasibility or the probability of successfully constructing the design and achieving design goals may be tradeoffs in some design choices. Cost and performance may also be traded off for each of the design choices. The choice between alternatives may not always be clearly defined as the impact on each of the system elements must be assessed along with the resulting interactions. In Table 8.3.2.1-2, the ongoing and planned tradeoff analyses are listed along with their related issue. No special site data are required for design resolution other than that needed for the general underground facility design. Only those that significantly impact the design and performance of the system are listed. The many other analyses of less significant impact are not mentioned.

8.3.2.1.4 Repository modeling

This section identifies and describes the needs for numerical of models and codes for repository design analyses. These numerical models are derived from conceptual models of system and subsystem response of the host rock to excavation and waste emplacement.

The need for a particular conceptual model results from goals established through the issue resolution strategy. From these conceptual models, numerical models are developed.

This section addresses the models and codes intended to be applied to geomechanical, ventilation, seismic, and safety analyses. The testing and evaluation of these models and codes, including verification and validation, are discussed in Section 8.3.5.20.

Table 8.3.2.1-2. Nevada Nuclear Waste Storage Investigations Project design tradeoff analyses

Design tradeoff analyses	Related issue
Horizontal versus vertical waste emplacement orientation (includes separate cost, performance, and technical feasibility analyses, as well as single-package short-hole and multipackage long-hole variants)	4.4 (Section 8.3.2.5)
Underground ventilation reversibility (use or not use)	4.2 (Section 8.3.2.4)
Selection of material handling method, hoist type, and waste transporter	4.4
Selection of repository orientation	1.11 (Section 8.3.2.2)
Underground emplacement of backfill	1.11
Selection of areal power density of emplaced waste	1.11
Selection of borehole spacing and length and waste standoff	1.11
Selection of excavating technique(s)	1.11, 4.4
Selection of excavation geometry and dimensions	4.4
Selection of underground rock support systems	4.4

For geomechanical analyses, loads imposed upon the rock mass from excavation and heat generating waste will be evaluated (Issue 1.11, configuration of underground facilities, Section 8.3.2.2). For ventilation analyses, design of the ventilation system will include equipment and worker health and safety considerations (Issue 4.2, nonradiological health and safety, Section 8.3.2.4). For seismic considerations, hazards due to ground and fault motion will be analyzed to determine the potential effects of underground nuclear events and earthquakes upon surface and subsurface facilities (Issues 4.4, technical feasibility Section 8.3.2.5, and 1.11). Safety analyses include both radiological concerns (Issue 2.7, repository design criteria for radiological safety, Section 8.3.2.3) and nonradiological concerns (Issue 4.2).

8.3.2.1.4.1 Geomechanical analyses

Geomechanical analyses consider mechanical, thermal, and thermo-mechanical response of the rock mass through the emplacement and retrieval periods. Within the geomechanical area, the goals cited indicate the need to understand the response of the host rock to excavation and thermally induced loads. Excavation-induced loads depend primarily on the in situ stress field with additional stresses resulting from the geometry of the opening considered. Thermal loads depend primarily on magnitude of individual or combined heat sources. Heat is transmitted through the rock mass by considering the thermal properties of the rock and the heat transfer mechanism; thus, these loads vary with time and position. The effects of excavation-induced loads are first evaluated and then the effects of thermal loads are evaluated.

The current understanding of mechanical response is that, in general, the fractured rock mass can be treated as an elastic, elastic-plastic, or compliant-jointed medium (Section 6.4.2). Additionally, quasi-discrete and distinct-element models will be considered to evaluate the behavior of isolated joints, intersecting joints, and possibly rock-mass response. The current understandings of the mechanical response of the fractured tuff have been based on and supplemented by three integrated sources of data: (1) field studies of the local and regional geology of the site (Chapter 1), (2) laboratory and field data indicative of the mechanical and thermal response of the rock from Yucca Mountain (Chapter 2, Introduction), and (3) laboratory and field experiments data collected in situ at nearby Rainier Mesa (Section 2.3.3). The mechanical response considered in a given analysis or set of analyses may depend on the scale, loading, and boundary conditions of the problem or the purpose of the analyses.

The approach to understanding and predicting mechanical response has been to use progressively more complex models through the course of design, performance, and safety analyses. For example, standard engineering practices are often applied at the onset to provide initial guidance to developing repository design. This practice is qualified by data available before site characterization. The resultant preliminary design warrants evaluation and confirmation through use of boundary element and finite element methods.

Three types of analytical tools are being developed to provide perspectives of the rock mass mechanical response. These tools will be applied to address concerns of Issues 1.11 (configuration of underground facilities (postclosure), Section 8.3.2.2); 2.4 (retrievability, Section 8.3.5.2); 4.2 (nonradiological health and safety, Section 8.3.2.4), and 4.4 (preclosure design and technical feasibility, Section 8.3.2.5). The analytical tools are

1. Tunnel index methods (Barton et al., 1974a; Bieniawski, 1974) that are empirical methods that permit conclusions to be made regarding ground support requirements. As yet, these methods do not account for the effects of heat.

2. Calculations using boundary element techniques (numerical methods that treat the rock mass as an elastic media) will be used for an initial degree of confirmation or qualification to be placed on

ground support requirements determined by the tunnel indexing methods. The effects of excavation and heat may be included in the analysis. Rock strength may be used to interpret results. These methods allow efficient parametric studies to be undertaken in which design tradeoffs and potential effects of parameter sensitivities to design can be evaluated through the predictions of deformations and stress at specific locations as a function of time. The usefulness of boundary element methods will be tested through comparison with closed-form analytic solutions, finite-element codes, and underground exploration.

3. The predominant calculational tool for planned license application analyses will probably be the finite-element method. Thus far, this method allows for modeling the most complex combinations of geometries, boundary conditions, and material behavior. Calculations by this method, which treats the rock mass as an elastic, elastic-plastic, or compliant-jointed medium, will attempt to confirm or qualify the conclusions drawn from tunnel indexing and boundary-element methods based on the effects of excavation and heat predicted throughout the area of interest as a function of time. The finite-element method has the potential to consider rock strength, fracture slip, and fracture deformability either as part of the computation or as useful to interpret results. Also, ground-support (rock-support interactions including thermal effects) can be modeled using this method. Finite-element codes will be tested through comparison with closed-form analytic solutions, boundary-element codes, underground exploration, and laboratory and field testing.

Our current understanding is that the dominant heat transfer mechanism in the unsaturated tuff is temperature-dependent conduction. These understandings are based on a data base of laboratory and field tests and analyses (Section 2.5.3, relationship between intact rock and large-scale properties). The types of analytical tools being developed to provide perspectives of the rock mass thermal response to address Issues 1.11 (configuration of underground facilities (postclosure), Section 8.3.2.2), 4.2 (nonradiological health and safety, Section 8.3.2.4), and 4.4, (preclosure design and technical feasibility, Section 8.3.2.5), include

1. An analytic solution for heat conduction for finite cylinder heat sources with a decaying exponential source term with time and linear superposition of sources. This analytical tool will serve the purpose of making preliminary design assessments for the repository. This method will be tested using closed-form analytic solutions.

2. An analytic solution for the heat conduction for infinite line heat sources that may be constant or exponentially decaying with time. This analytical method is an integral part of the boundary-element method used to perform design and sensitivity analyses. This method will be tested using closed-form analytic solutions.

3. A numerical model capable of steady and transient linear and nonlinear thermal conduction analyses in at least two dimensions. Possible boundary conditions include constant temperature at a node, constant or time-dependent temperature along a side, adiabatic surface, forced convection, natural convection, and thermal radiation. Material properties (densities, specific heats, and conductivity tensors) may be dependent on temperature. This method will be tested using closed-form analytic solutions, benchmarking activities (Section 8.3.5.20), and laboratory and field experiments. Heat transfer codes similar to the ones being considered have been successfully applied to analyses of heat transfer in salt (Waste Isolation Pilot Plant and Project Salt Vault), granite (Stripa and Spent Fuel Test-Climax), and tuff (SCP Sections 2.5.2.1.1 and 2.5.3). These codes will be tested to show their applicability to partially saturated tuff at the repository horizon because the currently existing studies are not sufficient. The results of these analyses are used as input for thermomechanical analyses.

Our current understanding of the combined contributions of the excavation and thermal effects upon rock-mass response (termed the thermomechanical response) is based on laboratory and field investigations of the thermomechanical response of rocks at the site (Section 2.5, thermal and thermomechanical properties--large scale). Based on this understanding, two methods are currently being applied to predict thermomechanical response. In the first, using boundary-element techniques, thermal stresses and displacements are calculated by treating the thermal stress and the initial stress as a time-varying boundary condition. In the second, using finite-element techniques, mechanical responses from excavation and thermal responses from the heat source are separately analyzed, and then the thermal results are input to the mechanical analysis to determine the thermomechanical response.

The types and scales of analyses being considered to address Issues 1.11, 4.2, and 4.4 include the following:

1. The state of stress and deformation in the vicinity of boreholes, rooms, access ways, shafts, ramps, and the repository will be studied to determine short- and long-term stability through analyses in which the thermomechanical response resulting from excavation and subsequent thermal loading is assessed.

2. Surface uplift and subsidence will be studied to determine repository scale manifestations of short- and long-term thermomechanical response resulting from excavation and subsequent thermal loading (e.g., to aid in establishing acceptable areal power densities).

3. The state of stress and deformation resulting from excavations and construction of the surface facilities will be studied to ensure structural integrity and safety of the facilities throughout the course of operations.

4. Rock-mass deformation properties (anisotropic elastic properties) will be calculated by applying state-of-the-art numerical techniques (compliant joint models) to the current data base of intact rock and

fracture characteristics. Such anisotropic properties will be included in stability analyses as warranted.

8.3.2.1.4.2 Seismic analyses

For seismic considerations, hazards due to vibratory ground motion and surface fault rupture will be analyzed to determine the potential effects of underground nuclear events and earthquakes upon surface and subsurface facilities. Currently, to satisfy site characterization information needs for Design Issues 1.11 (configuration of underground facilities, Section 8.3.2.2) and 4.4 (preclosure design and technical feasibility, Section 8.3.2.5), as well as for Investigations 8.3.1.17.2 (fault movement) and 8.3.1.17.3 (seismicity); the phenomena being considered for analyses include

1. The attenuation of ground motion with depth (both for acceleration and frequency) as it applies to surface and subsurface facilities.

2. The effect of local geology upon seismic wave propagation and direction.

3. Fault activities at the site including total displacements, displacement rates, evidence of surface rupture, type and orientation, and age of recent activity of the faults in the site area.

4. Seismic hazards related to ground motion and surface rupture resulting from natural earthquakes.

5. Ground motion at any point in the repository horizon as a result of seismic loads, its effect on the state of stress and deformation, and the stability of underground openings.

8.3.2.1.4.3 Ventilation analyses

Ventilation analyses will be conducted initially to size and design the ventilation system and to assess its performance during the course of operations. Even in the unsaturated environment, removal of some water in the form of humidity will be accomplished by the ventilation system. The codes being considered for this work will be ones that have been used extensively in the past. Analyses may be attempted that could qualify these codes based on current applications of these codes at underground operations. Since the use of these codes in the past has not routinely included thermal effects to the extent expected for the repository, the codes should be qualified for that purpose. The types of analyses being considered to help address Issues 1.11 (configuration of underground facilities, Section 8.3.2.2), 2.7 (repository design criteria for radiological safety, Section 8.3.2.3), 4.2 (nonradiological health and safety, Section 8.3.2.4), and 4.4 (technical feasibility, Section 8.3.2.5), include

1. Analyses to ensure worker safety in the context of maintaining appropriate air quality for dust, humidity, radon daughter products, and temperature considerations.

2. Analyses to ensure that requirements for equipment operations are met.

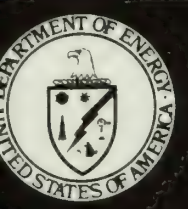
8.3.2.1.4.4 Safety analyses

Safety analyses will be conducted in addressing Issues 2.7, repository design criteria for radiological safety, and 4.2, (nonradiological health and safety). For Issue 2.7, analyses will ensure that limits of radiological exposure of workers and the public are met. Important to these analyses are the source terms and configurations of the underground and surface facilities coupled with the operations plan for the facilities. Codes being considered for this work will be ones that have been proven through extensive past use in the nuclear industry.

For Issue 4.2, analyses will be used to ensure worker health and safety in the daily course of operations. These analyses are similar to those listed in Sections 8.3.2.1.4.1 and 8.3.2.1.4.3.

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)



Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.2.2, Configuration of Underground Facilities (Postclosure)

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.2.2 Issue resolution strategy for Issue 1.11: Have the characteristics and configurations of the repository and repository engineered barriers been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.133 and (b) provide information for the resolution of the performance issues?

The postclosure design criteria of 10 CFR 60.133 addressed by this issue require that the underground facility and engineered barrier system be designed to

1. Contribute to containment and isolation.

2. Assist the geologic setting in meeting performance objectives.

3. Take into account the thermal and thermomechanical response and the need for sufficient flexibility to accommodate site-specific conditions.

This postclosure design issue provides the mechanism for identifying repository design characteristics and configurations important to the resolution of Key Issue 1, quantifying how these characteristics and configurations are in compliance with 10 CFR 60.133, and incorporating postclosure performance concerns into the design. Characteristics and configurations considered in developing the approach to this issue include repository depth, dip, orientation, geometry, layout, access location, thermal loading, drainage or moisture control, construction materials, backfill, excavation techniques, and opening stability.

The approach to resolving this issue will be to establish tentative performance goals through the issue resolution process and to develop reference postclosure designs of the repository that are in compliance with these goals. The impact of design characteristics and configurations on the postclosure performance of the repository will be documented in a series of topical reports. The reference postclosure design will be documented in the reference information base (RIB) (together with other components of the overall design) and in major design documents for use in postclosure performance assessments.

In practice, this issue will be resolved in step with the planned design stages. Specifically, preliminary assessments and design concepts are an integral part of the conceptual design summarized in Chapter 6. Updating of this information will continue through the advanced conceptual design and the license application design. Advancing from one step to the next in the design process requires that the goals of the issue be met or that there be reasonable expectancy that they will be met as detailed studies are completed in succeeding phases of the design.

The general approach used to determine compliance with 10 CFR 60.133 and to provide adequate information to support resolution of performance issues, which is summarized in Figure 8.3.2.2-1, is to

1. Apply the issue resolution process as a means of establishing the overall logic of Figure 8.3.2.2-1, specifically identifying the performance goals of the issue.

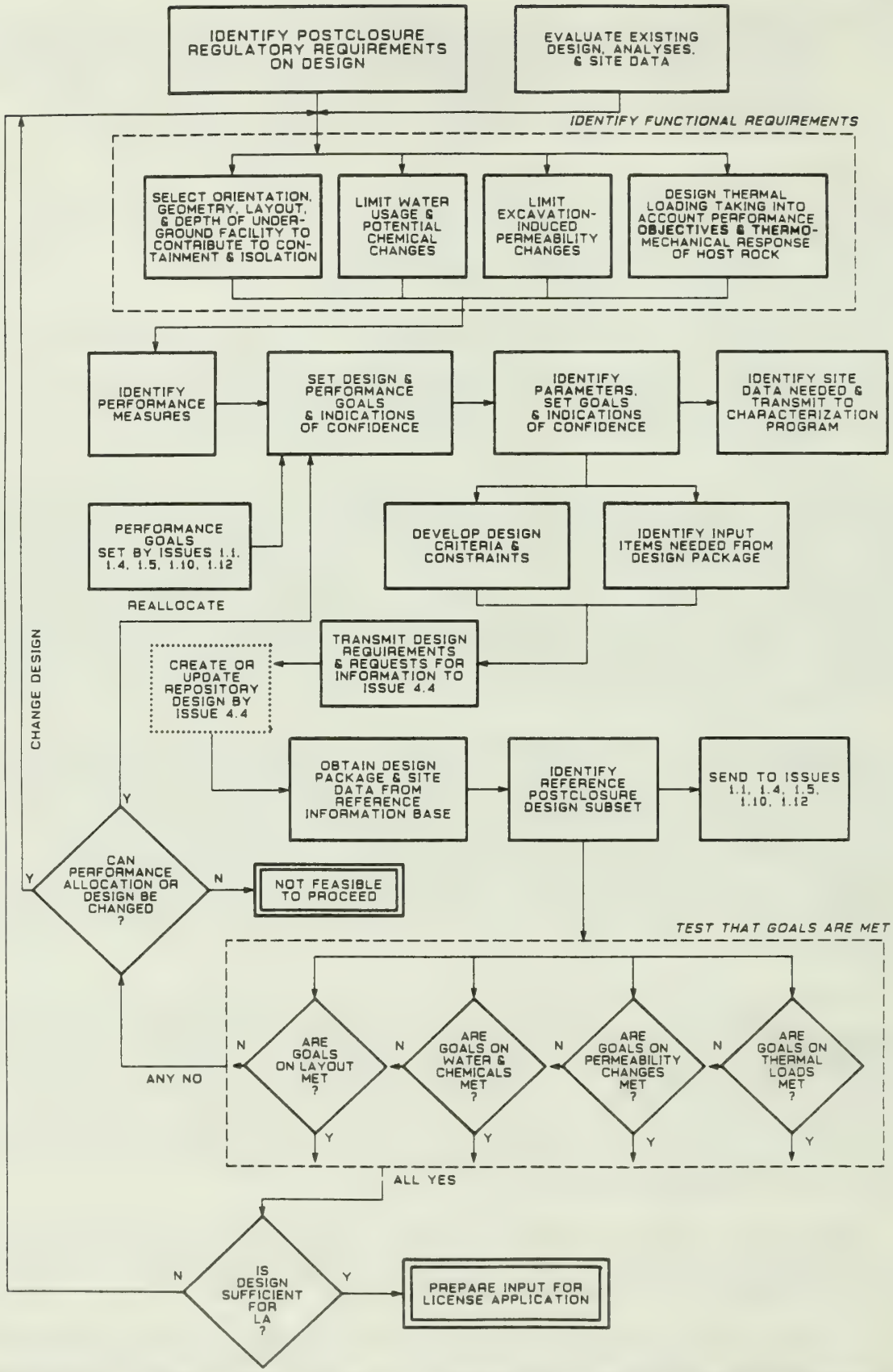
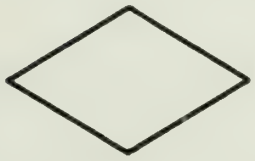


Figure 8.3.2.2-1a. General approach for Issue 1.11 (configuration of underground facilities–postclosure). See Figure 8.3.2.2-1b for legend. Section 8.3.2.1 describes the relationships and interfaces between design and performance issues.

LEGEND



ACTIVITY PERFORMED TO RESOLVE ISSUE



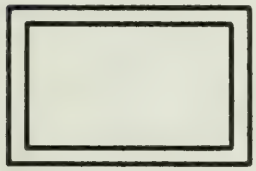
TEST TO DETERMINE SUBSEQUENT ACTIVITY



ACTIVITY PERFORMED BY INDICATED ISSUE



ACTIVITY WITH MULTIPLE SIMILAR ACTIVITIES OR TESTS



DECISION ABOUT ISSUE RESOLUTION

Y - YES N - NO LA - LICENSE APPLICATION

Figure 8.3.2.2-1b. Legend for Figure 8.3.2.2-1a.

2. Perform technical studies (design activities) to evaluate compliance with the goals, complete reference calculations for use by other issues and perform sensitivity studies that evaluate data needed for design (middle part of Figure 8.3.2.2-1).

3. Establish data requirements (accuracy and confidence) as guidance to data gathering, assimilate site and waste package data, and establish RIB inputs (data request and inputs on Figure 8.3.2.2-1).

4. Establish reference postclosure design as the basis for postclosure performance assessment of the repository.

The goals may be modified, extended, or eliminated as more detailed evaluations are completed.

A significant part of the role of this issue (1.11) in resolving Key Issue 1 is to provide the interface between postclosure performance and design (Figure 8.3.2.2-1). The design is produced by Issue 4.4 (Section 8.3.2.5). This issue provides the interface to postclosure performance issues by taking their performance goals and converting them into design requirements that can be used by Issue 4.4 to control the design through the repository design requirements document. Figure 8.3.2.2-1 shows Issue 1.11 as the bridge between the total system and Issue 4.4. The relationship between performance issues, this issue, and the design is embodied in the logic of Figure 8.3.2.2-1.

Regulatory basis for the issue

The parts of 10 CFR 60.133 that apply to postclosure performance and are addressed by this issue are listed in the following discussion. All parts of 10 CFR 60.133 not listed in the following discussion are considered preclosure criteria and are therefore addressed by other issues, specifically Issues 2.3 (accidental radiological releases, Section 8.3.5.4); 2.7 (repository design criteria for radiological safety, Section 8.3.2.3); 4.2 (nonradiological health and safety, Section 8.3.2.4); and 4.4 (preclosure design and technical feasibility, Section 8.3.2.5).

10 CFR 60 section	Subject applicable to Issue 1.11
133(a)(1)	Design layout and engineered barriers to contribute to performance
133(b)	Accommodate site-specific conditions
133(e)(2)	Design to reduce deleterious rock movement
133(f)	Select excavation methods that limit preferential pathways
133(h)	Assist performance of geologic setting in meeting the postclosure performance objectives
133(i)	Predict thermal and thermomechanical response

The general standard required for compliance with these regulations is "A reasonable assurance . . . that the objectives and criteria will be met" (10 CFR 60.101(a)(2)) based on predictive models" "supported by using an appropriate combination of such methods" (10 CFR 60.21(c)(1)(ii)(F)) (Section 8.3.2.2.4).

To understand the scope of these regulations and how they apply to this issue, some discussion is provided below on the work to be conducted under this and related issues.

The characteristics and configurations of the waste package and its interaction in the near-field environment are governed by 10 CFR 60.135, which is addressed by Issue 1.10 (waste package characteristics (postclosure) (Section 8.3.4.2), and hence is considered an interface to this issue. As such, Issue 1.10 places requirements on this issue that are reflected in the choice of processes, performance measures, and performance goals of this issue.

The NRC definition of the underground facility excludes shafts, boreholes, and seals for shafts and boreholes but does not specifically exclude drift seals. Drift seals could be considered part of the underground facility, and, in turn, part of the engineered barrier system. However, they are explicitly addressed by Issue 1.12 (shaft and borehole seals characteristics, Section 8.3.3.2), and governed by 10 CFR 60.134 and 10 CFR 60.112. Both their function and time of emplacement are very closely allied with the shaft and borehole seals. Issue 1.12 established the requirements for sealing and how sealing will be accomplished. Thus, seals, including drift seals are considered to be an interface to this issue rather than a part of this issue. As such, Issue 1.12 places requirements on this issue that are reflected in the choice for processes, performance measures, and performance goals of this issue.

To provide the technical basis for meeting the higher level findings (Issue 1.9, Section 8.3.5.18), this design issue (1.11) must, in addition to compliance with 10 CFR Part 60, address the requirements of 10 CFR Part 960. This is done by using 10 CFR Part 60 to organize the issue resolution strategy while ensuring that the goals determined by the issue resolution approach include 10 CFR Part 960 requirements. Specific applicable parts of 10 CFR Part 960 include Subpart C, Sections 4-2-3 (Rock Characteristics) and 4-2-5 (Erosion).

Approach to resolving the issue

The issue resolution strategy for this issue started from the regulations and applied four steps: (1) functions, (2) processes, (3) performance measures, and (4) performance goals and confidence.

The "function" step is an expression of what must be done by the System Element 2.0, postclosure waste disposal system (Section 8.2.1). The functions for this issue were derived directly from 10 CFR 60.133 and provide the means for compliance of the design of the underground facility with the regulations. All the subsections of 10 CFR 60.133 noted under the regulatory basis are important to resolving this issue and are contained within these functions.

The "process" step describes how the function will be accomplished. Processes were assigned so that each function would be complete in its contribution to resolution of the issue. The processes identified for Issue 1.11 are closely related to the design activities for the issue. Because the system elements listed in the System Element 2.0 (postclosure waste disposal system) requirements are not currently defined to the level of detail of characteristics and configurations of the underground facility required by this issue, a separate checklist of such characteristics and configurations was prepared. This list was then used to guide selection of processes and was used in workshops on this issue to ensure that the list of processes was reasonable and essentially complete.

The "performance measures" step identifies the measure that will allow a determination of whether the process is being performed as required by the function. That is, to resolve the issue, the performance measure will serve as the indicator in determining how well the function is performed.

Each performance measure has an associated "goal and level of confidence" step. The goal is the value for the performance measure that will be adequate for the issue to be favorably resolved, and the level of confidence is an indication of the importance assigned to meeting the goal.

The assignment of these performance measures and associated performance goals and levels of confidence was based on professional judgment and peer reviewed in a series of workshops held in Albuquerque, New Mexico, in the spring of 1986. Completing this issue resolution completes the approach to resolving Issue 1.11 (configuration of underground facilities (postclosure)).

The results of the issue resolution approach for Issue 1.11, including each process, performance measure, and performance goal and associated confidence required, are discussed by function in the following paragraphs.

The four functions that the postclosure waste disposal System Element 2.0 (postclosure waste disposal system) must perform to resolve this issue are given in the following list together with the regulatory section they address. These functions were selected so that there is a direct correlation between the functions and the postclosure design criteria as expressed in 10 CFR 60.133.

1. Select orientation, geometry, layout, and depth of the underground facility to contribute to containment and isolation, taking into account flexibility to accommodate site specific conditions (10 CFR 60.133(a)(1) and 10 CFR 60.133(b)).

2. Limit water usage and potential chemical changes during construction and operations of underground facility so as to not adversely affect performance of natural and engineered barriers following permanent closure (10 CFR 60.133(a)(1) and 10 CFR 60.133(h)).

3. Limit potential for excavation-induced changes in rock mass permeability during construction of the underground facility so as to not adversely affect performance of natural and engineered barriers following permanent closure (10 CFR 60.133(f)).

4. Design thermal loading taking into account performance objectives and thermomechanical response of host rock (10 CFR 60.133(i), 10 CFR 60.133(e)(2), and 10 CFR 60.133(h)).

In this section, the specific processes contributing to each of the four functions are identified. Subsequently, one or more performance measures and corresponding performance goals are selected for each of the processes. The link between the processes, performance measures, and performance goals is illustrated by use of a series of tables in which the performance goals are expressed quantitatively whenever possible and appropriate. The tables are supported by descriptive text intended to provide a brief background and rationale for the tabulated material. The text and tables also identify interfaces with other issues. Such interfaces exist either when resolution of this issue contributes to resolution of another, or when resolution of another issue automatically satisfies performance measures identified here.

The tables identify two types of processes; namely, those upon which reliance is placed and those that provide additional, or backup, assurance that the function of the repository and its engineered components meet the postclosure performance criteria. The confidence with which the performance goals associated with each process need to be met at the license application stage are designated as high, medium, or low. Those designated as high are considered to be critical to providing reasonable assurance that the repository system will comply with the performance criteria. Definition of the approach to be used to meet the goals, with appropriate level of confidence, will ensure identification of the type and quality of the data required to support resolution of the performance issue.

Function 1: Select orientation, geometry, layout, and depth of the underground facility to contribute to containment and isolation, taking into account flexibility to accommodate site-specific conditions

To meet the requirements of 10 CFR 60.133(a)(1) and 10 CFR 60.133(b), the repository will be configured so that its orientation, layout, geometry, and depth contribute to or do not adversely affect containment and isolation. The primary system elements affected by function 1 are the disturbed zone (System Element 2.1.1) and the repository engineered barriers (System Element 2.2.2). Processes that contribute to meeting the function, and the related performance measures and goals are listed in Table 8.3.2.2-1. The following discussion treats the processes in three groups, which deal with the repository configuration, the environment for the waste containers, and the need for flexibility.

Repository configuration

The NWPA (1983) requires that there be sufficient space within the repository to accommodate the equivalent of 70,000 metric tons of uranium. As indicated in Table 8.3.2.2-1, this criterion must be met subject to goals relating to depth of overburden and an objective to stay above the water table in unsaturated, welded tuff of the Topopah Spring Member. Those goals were established to ensure compliance with containment and isolation performance criteria for the facility. They must be met during design through

Table 8.3.2.2-1. Performance measures, goals, and needed confidence for selecting orientation, geometry, layout and depth of underground facility (postclosure design function 1)[a] (page 1 of 3)

Process					
Possible	Relied on	Performance measure		Tentative goal	Needed confidence
Vary depth, dip, orientation and lateral extent of underground facility to provide host rock with favorable containment and isolation characteristics	Yes	Usable area: Is usable area adequate for 70,000 metric tons of uranium (MTU) of waste?	1-A[b]	Area available >> area needed - >200 m overburden - stay in TSw2[c] - have disturbed zone stay >70 m above water table[d] - stay in primary area - areal power density (APD) <allowable far-field APD - probability <0.1 in 1,000 yr that >0.5% of waste packages will be breached by tectonic processes or events - offset from exploratory boreholes >15 m (cf. Issue 1.12)	High High Medium High Medium High High High
Select emplacement borehole orientation and design to limit potential for adverse effects	Backup	Performance measures as defined by Issues 1.1, 1.6, and 1.10 will be used as part of choosing borehole orientation[e]	1-B	Performance goals as defined by Issues 1.1, 1.6, and 1.10 will be used as part of choosing borehole orientation	Medium
Limit the amount of water in contact with container to provide favorable isolation and containment environment	Yes	Regions of dehydration or condensation and drainage pattern	1-C	Design subsurface facility so that convection and natural drainage is away from containers and so that goals of Issues 1.10 and 1.12 can be met[f]	High
Skip and isolate unfavorable areas	Yes	Ground quality (technical feasibility performance measure)	1-D	Goals for determining technical feasibility of underground development considering local variability will be set by Issue 4.4	High

Table 8.3.2.2-1. Performance measures, goals, and needed confidence for selecting orientation, geometry, layout and depth of underground facility (postclosure design function 1)[a] (page 2 of 3)

Process		Performance measure		Tentative goal	Needed confidence
Possible	Relied on				
Skip and isolate unfavorable areas (continued)		Extent of change in	1-E	Emplace in ground that satisfies	
		- saturation		- average saturation: 75%[g]	High
				- local saturation <90%[g]	Low
		- water chemistry		- water chemistry requirements established in Issue 1.10[h]	Medium
		Distance from ground with unfavorable properties	1-F	Stay far enough away to satisfy goals of 1-E above[i]	Medium
Adjust thermal load to accommodate local conditions	Yes	Temperature (to limit potential for adverse geochemical, etc. effects on the host rock)	1-G	Goals (4-O, 4-P, 4-R, 4-U, and 4-V) for determining allowable temperatures are set as part of function 4 (Table 8.3.2.2-4) of this issue	High
		Postclosure rock movements within acceptable limits under thermal loads	1-H	Goals (4-Q and 4-W) for determining if rock meets postclosure thermomechanical criteria will be set by function 4 (Table 8.3.2.2-4) of this issue	Medium

[a]The issues referenced in this table and its footnotes are addressed in the following sections: Issue 1.1 (total system performance, Section 8.3.5.13), Issue 1.6 (ground-water travel time, Section 8.3.5.12), Issue 1.10 (waste package characteristics-postclosure, Section 8.3.4.2), Issue 1.12 (seal characteristics, Section 8.3.3.2), and the climate program (Section 8.3.1.5).

[b]1-A indicates function 1 and goal A. This designator is carried over to Table 8.3.2.2-5 to associate data of that table with goals of this table.

[c]Goal is to stay in the TSw2 unit (low lithophysal Topopah Spring Member), but TSw1 (lithophysal Topopah Spring) may be considered. See Chapter 2 for complete description of units.

[d]The distance from the disturbed zone to the water table should be 70 m or more; preferably this should be 70 m of CHn (Calico Hills nonwelded unit).

[e]Design factors that will be considered in performance review of borehole orientation include drift size, extraction ratio, standoff distance, potential fault/fracture effects, borehole hydrology, liner effects, potential abnormal conditions, etc.

Table 8.3.2.2-1. Performance measures, goals, and needed confidence for selecting orientation, geometry, layout and depth of underground facility (postclosure design function 1)[a] (page 3 of 3)

Footnotes (continued)

[f]Specific requirements of Issue 1.12 include (1) locate surface portals in nonflood prone areas; (2) restrict the number of shafts and ramps; (3) retain capability to emplace seals at base of shafts; (4) provide adequate storage capacity at base of shafts; (5) grade drifts to drain away from emplacement areas; (6) ensure drift floors can be reconditioned to enhance drainage; (7) provide adequate storage at low point of subsurface facilities before water enters emplacement drifts; and (8) establish drainage of shops, etc., toward exploratory shaft 1 (ES-1) and men and material (MM) shafts and of emplacement areas away from ES-1 and MM shafts. Specific requirements of Issue 1.10 include keeping containers dry through drainage and maintaining temperatures greater than the boiling point of water for more than 300 yr.

[g]Goal is to emplace waste in areas consistent with Issue 1.1 by requiring average emplacement saturation to be about 75% or less and local saturation around emplacement boreholes to be less than 90%. Intent of goal is to assure that perturbations to the site due to construction, operations, and the addition of heat will not cause saturated conditions.

[h]Water chemistry goals as set by Issue 1.10. Conditions should not be disturbed from predevelopment conditions by more than a specified amount.

[i]Actual standoff is determined by conditions around the ground with unfavorable properties by requiring that goal 1-E be met. Faults are explicitly incorporated into the design through goals 1-A, however, the anomalous conditions of concern in goal 1-E (saturation and geochemistry) are most likely to occur near faults. During conceptual design the offset of Ghost Dance (approximately 14 m) was used to estimate how much bigger the layout would be if such a standoff were incorporated (SCP-CDR Appendix M (SNL, 1987)). If ground with unfavorable properties is found within the ESF, a better estimate (than offset) of appropriate standoff can be made.

appropriate selection of the depth, dip, orientation, and lateral extent of the underground facility. Postclosure considerations are important to that design process because the areal power density (APD) must be selected so as to meet temperature, stress, and displacement criteria discussed under this issue. In addition, the repository layout and dip must be selected so as to assist drainage and contribute to maintaining the container environment goals established under Issue 1.10 (Section 8.3.4.2), waste package characteristics (postclosure).

The APD is an average figure for the repository. The thermal output of individual containers and their spacing and orientation become important when considering near-field performance criteria. Preliminary evaluations indicate that the orientations of the underground openings relative to the in situ stress and fracture geometry may not be primary design considerations (Section 6.4.2 of the Site Characterization Plan-Conceptual Design Report (SCP-CDR) (SNL, 1987). However, potential performance differences between the horizontal and vertical emplacement options will be evaluated. The selected option must meet isolation and containment requirements, and contribute to meeting the requirements of other issues, namely, Issues 1.1 (total system performance, Section 8.3.5.13), 1.6 (ground-water travel time, Section 8.3.5.12), 1.10 (waste package characteristics (postclosure), Section 8.3.4.2), and 4.4 (technical feasibility, Section 8.3.2.5). The final recommendation regarding the disposition of the waste will be documented in the reference postclosure design.

Container environment

A goal to limit the amount of water that will come in contact with the waste container is established in Issue 1.10 (Section 8.3.4.2), which is concerned with waste package design. Measures taken to meet this goal and thereby contribute to containment and isolation include location of the repository in an unsaturated host rock; development of an underground layout that enhances natural drainage away from the containers; and selection of a design basis thermal loading (APD) that maintains temperatures above the in situ boiling temperature of water at the container surface for the first 300 yr after repository closure. The use of seals to reduce the entry of water into the underground facility will also affect container environment; seals are addressed in Issue 1.12 (seals characteristics, Section 8.3.3.2).

In Table 8.3.2.2-1, a general requirement to define the regions of dehydration and condensation and the pattern of drainage within the underground facility is identified. The amount of moisture that is anticipated to come in contact with the containers during the postclosure period will be considered during design and will be the subject of performance assessment. Performance measures and goals relating to thermal environment of the canister are discussed further under function 4.

Flexibility

The design of the repository will be sufficiently flexible that there will be freedom to respond to conditions encountered underground during construction and emplacement. Two possible options for responding to adverse ground conditions are identified in Table 8.3.2.2-1. These are either to skip and isolate unfavorable areas or to adjust the thermal load locally.

Function 2: Limit water usage and potential chemical changes.

In conformance with the regulatory requirements stated in 10 CFR 60.133(a)(1) and 10 CFR 60.133(h), the engineered barriers will contribute to isolation and containment and will assist the geologic setting in meeting performance objectives. Two processes are identified as important to assuring that the engineered barriers (System Element 2.2.2) adequately satisfy those requirements. These are concerned with avoiding potentially adverse changes in the chemical environment and the degree of saturation of the host rock. These two processes and their related performance measures and performance goals and confidence are listed in Table 8.3.2.2-2.

Limit adverse chemical changes

Potentially adverse chemical effects may arise, either directly or indirectly, as a result of materials introduced to the site during construction, operation, and decommissioning. Primary factors in meeting this functional requirement are the control of materials entering the repository.

In Table 8.3.2.2-2, cement and organics are identified as materials that may need to be controlled, because they may adversely affect the pH and chemistry of the natural ground water. Goals with respect to pH and chemistry changes as they impact the waste package and waste isolation have been established by Issue 1.10 (Section 8.3.4.2), and Issue 1.1 (Section 8.3.5.13). This issue (1.11) (Section 8.3.2.2) will establish the allowable postclosure material quantities and impose these constraints on Issue 4.4 (Section 8.3.2.5). During design, particular attention has focused on the amount of cement used for all construction and operations, and in particular for the preparation of the emplacement boreholes, and any organics in the flushing fluid used during drilling. The goals of controlling the quantities of cement and organics, which are identified in Table 8.3.2.2-2, can be met with the required confidence by development and implementation of operating procedures for the underground facility.

Limit and control water used during construction

Control of water used during construction of the shafts, access ramps, and the excavations of the underground facility is identified as a process in Table 8.3.2.2-2, because of the desire to limit the changes in the degree of saturation of the host rock and the water reaching the containers. The degree of saturation of the rock in the immediate vicinity of the waste containers is a concern. As a result, it will also be important to limit and control the nature and quantity of the flushing medium used during drilling holes and the water used for drilling and dust control during construction of the other excavations of the repository.

The present design basis is that the emplacement boreholes will be drilled dry, using a vacuum chip removal system, and that criteria will be developed for control of any water used during construction, operation, and decommissioning. Other measures to be taken to control the amount of water that will come in contact with the containers are discussed under functions 1 and 4. These include, respectively, planning the repository so the natural

Table 8.3.2.2-2. Performance measures, goals, and needed confidences for limiting water usage and potential chemical changes (postclosure design function 2)

Process		Performance measure		Tentative goal	Needed confidence
Possible	Relied on				
Limit adverse chemical changes by using acceptable materials and fluids	Yes	Type, quantity, and location of materials (including materials for seals):	2-I[a]	Requirements specified by Issues 1.10 and 1.12 (Sections 8.3.4.2 and 8.3.3.2) applied here	
		Quantity of concrete		Limit cement in emplacement boreholes and drifts to that required for proper construction[b]	Medium
		Quantity of shotcrete		Limit shotcrete in drift and access linings to that required for proper construction	Medium
		Quantity of grout for bolt anchors		Limit grout used for bolt anchors to that required for proper construction	Medium
		Quantity of organics		Limit organics in drilling fluids and explosive residues from blasting	High
Limit the amount of water used in construction, operation, emplacement of seals, and decommissioning to provide favorable containment and isolation environment	Yes	Net water from operations that remains in host rock at emplacement	2-J	Water usage should be limited so that saturation at emplacement does not violate goal 1-E, Table 8.3.2.2-1	High
				Limit water to that required for dust control and proper equipment function	
				Remove all excess water	

[a]2-I indicates function 2 and goal I. This indicator is carried over to Table 8.3.2.2-5 to associate data of that table with goals of this table.

[b]Quantities and chemical composition may be impacted by requirements related to postclosure performance objective for the waste package.

drainage is away from the waste containers, using seals to reduce the quantity of water that enters the repository, and maintaining container temperatures sufficiently high to maintain dry conditions around the waste containers during the first 300 yr following closure.

Function 3: Limit potential for excavation-induced changes in rock mass permeability

In conformance with requirements stated in 10 CFR 60.133(f) and 10 CFR 60.133(e)(2), the excavation method and the design of the underground openings of the repository will be selected so as to limit the potential for creation of preferential pathways to the accessible environment, particularly through deleterious rock movement and creation of new fractures in the rock mass. The system element contributing to satisfying this function is the disturbed zone (System Element 2.1.2). The disturbed zone is defined under Issue 1.6 (ground-water travel time, Section 8.3.5.12), as the region of the host rock in which there might be potentially adverse changes in the hydrologic properties (matrix permeability and porosity). Processes considered important to this function are identified in Table 8.3.2.2-3. Those processes are discussed individually in the following sections.

In addition to the potential for excavation-induced changes in rock mass permeability, thermal stresses can change fracture apertures and hence, fracture permeability. Goals controlling the potential for deleterious rock movement and preferential pathways that might result from thermal stresses have been established by performance allocation under function 4 (design thermal loading taking into account performance objectives and thermomechanical response of the host rock). Section 6.4.1 of the SCP-CDR (SNL, 1987) discusses the relationship of the current understanding of hydrologic processes in the unsaturated zone at Yucca Mountain to the goals established under function 4.

Permeability modification associated with excavation process

Damage to the rock mass that is associated with blasting can be limited through the use of appropriate blast control methods. Such procedures are important design concerns since they potentially impact support and maintenance (Issues 4.2 (Section 8.3.2.4), nonradiological health and safety, and 4.4 (Section 8.3.2.5), technical feasibility). Analyses in the SCP-CDR suggest that they are less important to postclosure performance concerns because movement of ground water is generally expected to be through the matrix rather than along fractures (see the Section 6.4.1 of SCP-CDR (SNL, 1987) for a complete discussion), and blast-induced fracturing typically extends only a short distance from an excavation compared with the distance to emplaced waste. Similarly, the use of drilling as the emplacement borehole construction method is important to preserving stability of the boreholes. Stable boreholes are important to maintaining the retrieval option during the preclosure period (Issue 2.4 (waste retrievability, Section 8.3.5.2)) and to meeting waste package criteria (Issue 1.10 (waste package characteristics--postclosure, Section 8.3.4.2)), as well as to minimizing block motion (caving) above the borehole that might result in adverse effects on waste package containment (Issue 1.10).

Table 8.3.2.2-3. Performance measures, goals, and needed confidences for limiting potential for excavation-induced changes in rock mass permeability (postclosure design function 3)

Process		Performance measure		Tentative goal	Needed confidence
Possible	Relied on				
Limit magnitude and extent of blast-induced permeability change by blast control	Backup	Permeability change due to blasting should not cause a change in disturbed zone boundary or unnecessarily complicate seal evaluation and emplacement	3-K[a]	Permeability change beyond 3 m should be less than one order of magnitude[b] (cf. Issue 1.6 (Section 8.3.5.12))	Medium
Limit potential for subsidence by limiting extraction ratio and drift size	Backup	Extraction ratio	3-L	Current design basis - Horizontal emplacement <10% - Vertical emplacement <30%	 High High
		Drift spans	3-M	<11 m	High
Backfill drifts at decommissioning	Backup	Amount of fill	3-N	Backfill to within 0.5 m of roof	Medium

[a]3-K indicates function 3 and goal K. This designator is carried over to Table 8.3.2.2-5 to associate data of that table with goals of this table.

[b]Drifts and emplacement boreholes; for description of constraints on shafts or seal areas see Issue 1.12 (Section 8.3.3.2).

Limit potential for surface subsidence

Subsidence of the ground surface is observed to occur above mining excavations when a high proportion of the rock on a particular horizon is extracted. The possibility of subsidence can be reduced with a high degree of confidence, provided the span of any excavations is small and the pillars between excavations are large, and chiefly by minimizing the extraction ratio. For the repository, the requirements for containment and preservation of the retrieval option would be inconsistent with allowing significant roof falls or pillar damage. Hence, the potential for surface subsidence during the preclosure period must be excluded. In the longer term, the potential for subsidence will be limited by conservative pillar design and maintaining reasonably low extraction ratio. The role of backfilling is currently being investigated in subsidence control and creation of preferential pathways for water migration.

Limit postclosure drift collapse by backfilling

If the excavations of a repository are not backfilled before decommissioning, there is a potential for progressive collapse of at least portions of the underground excavations as the ground support system deteriorates. Whether such collapse constitutes a potentially adverse condition is addressed by this issue, by assessing if the potential for such collapse would cause the goals of performance issues to be violated (see function 4). The present design basis is that the underground excavations will be backfilled before closure of the underground facility.

Function 4: Design thermal loading, taking into account performance objectives and thermomechanical response of the host rock

As required by 10 CFR 60.133(i), the thermal loading of the repository will be selected so that the postclosure performance objectives will be met, taking into account the thermal and thermal-mechanical response of the host rock. In addition, there are performance objectives relating to environmental impacts at the ground surface above the repository. Because these are postclosure requirements, the repository engineered barriers (System Element 2.2.2) and the far-field (System Element 2.1.2) are identified as the most important to ensuring that these performance objectives are satisfied.

Table 8.3.2.2-4 identifies six processes that contribute to meeting this functional requirement. Of these six, three are directly concerned with the thermal field in the immediate vicinity of the waste package and below the underground facility, and two are related to potentially deleterious rock movement. The remaining process is concerned with surficial effects.

Limit temperature change in adjacent strata

The most credible path to the accessible environment is via the groundwater system. Because the repository is to be constructed in partially saturated material, this implies that the material between the underground facility and the water table below is important to the site performance. Some of the units below unit TSw2 (including the Calico Hills unit) are subject to mineralogic changes when they dehydrate. This may cause chemical and physical effects that could be detrimental to waste isolation. Accordingly,

Table 8.3.2.2-4. Performance measures, goals, and needed confidences for designing thermal loading taking into account performance objectives and thermomechanical response of host rock (postclosure design function 4) (page 1 of 2)

Process		Performance measure	Tentative goal	Needed Confidence
Possible	Relied on			
Limit temperature changes in selected barriers	Backup	Temperature	4-O[a] Limit temperature of CHn to <115C°[b]	Medium
			4-P Limit temperature of TSw3 to <115°[b]	Medium
Limit deleterious rock movement or preferred pathways	Backup	Potential for significant displacement (see Issue 1.1)	4-Q Relative motion <1 m at the top of TSw1[c] - No intact rock failure[d] - No continuous joint slip[e]	Medium
Limit impact on surface environment	Backup	Temperature	4-R Rise in surface temperature less than 6C°[f]	Low
		Surface uplift	4-S Surface uplift less than 0.5 cm per year[g]	Low
Vary borehole and drift spacing to control thermal loading and container temperature	Yes	Thermal loading	4-T Design basis thermal loading less than allowable thermal loading[h]	High
		Borehole wall temperature[i]	4-U Temperature <275°C	High
		Rock mass temperature[j]	4-V Temperature at 1 m from borehole <200°C[k]	High
Limit potential for borehole collapse	Yes	Stress, deformation, factor of safety, and potential rock fall	4-W Boreholes that do not load container beyond limits imposed under Issue 1.10 (Section 8.3.4.2)[l]	High
Limit corrosiveness of container environment	Yes	Time container is above boiling temperature of water (Issue 1.10)	4-X Majority of borehole walls above boiling temperature of water for >300 yr[m]	High

[a]4-O indicates function 4 and goal O. This designator is carried over to Table 8.3.2.2-5 to associate data of that table with goals of this table.

[b]Calculated with mean properties. See Issue 1.6 (Section 8.3.5.12) for a discussion of disturbed zone and basis for these goals.

Table 8.3.2.2-4. Performance measures, goals, and needed confidences for designing thermal loading taking into account performance objectives and thermomechanical response of host rock (postclosure design function 4) (page 2 of 2)

Footnotes (continued)

[c]Issue 1.1 requirement is that the relative motion of the rock be less than 1 m (Section 8.3.5.13). To provide confidence that the goal is met, Issue 1.11 provides the additional constraints under goal 1-Q.

[d]Unconsolidated material and disturbed zone excluded from intact rock failure criteria.

[e]Continuous joint slip from surface to disturbed zone or from disturbed zone to water table.

[f]Unit evaluation goal retained in performance allocation process. Further evaluation of this goal is planned.

[g]Unit evaluation natural analogue goal retained and converted to rate in performance allocation process.

[h]Allowable thermal loading (APD) will be determined by goals (o) through (s). Current design basis is "equivalent energy density" through 2,000 yr to 10 yr old average burnup spent fuel emplaced at 57 kW/acre (as per unit evaluation).

[i]Borehole wall temperature chosen so that spent fuel waste temperature will not exceed 350°C using current canister designs (cf. Issue 1.10).

[j]To ensure as-built facility does not violate bounds of properties investigated in license application and to limit the potential for adverse stress conditions due to high temperature thermal expansion of the rock.

[k]200°C at 1 m may be replaced with some other measure of the volume of rock that may exceed the bounds of temperature for which the rock properties were investigated for license application.

[l]Goal is that borehole calculations using average properties (rock and waste) and design basis geometry will result in stresses, deformations, and factors of safety that are indicative of stable conditions for the average package. This will imply reasonable confidence that the goal is met.

[m]Goal is that borehole calculations using average properties (rock and water) and design basis geometry will result in the majority of the borehole walls being above boiling for more than 300 yr. This will imply reasonable confidence that the goal is met.

a tentative performance goal of limiting the extent of those units that may be subject to dehydration due to increased temperature has been set. That goal, which is intended to minimize the extent of potentially adverse effects, should be dictated by performance assessment considerations, which are addressed under Issue 1.6 (ground-water travel time, Section 8.3.5.12).

Limit potential for deleterious rock movement or creating preferential pathways

During the postclosure period primary concern over deleterious rock movement or preferred pathways rests with maintaining the integrity of the natural barriers.

The thermomechanical effect most likely to affect natural barrier performance is permeability change. Away from the excavations, permeability change should be limited and occur primarily in existing fractures. Fracture permeability is not believed to be an important process in natural barrier performance (Section 6.4.1 of SCP-CDR) (SNL, 1987). The largest permeability changes will most likely be associated with rock movement around the emplacement boreholes, the emplacement drifts, or along faults. If the effects of such disturbances do not result in an extension of the disturbed zone, as described under Issue 1.6 (ground-water travel time), this should not impact the ability of the natural barrier to isolate the waste. Accordingly, limiting the potential for permeability changes is identified as a backup process.

An explanation of the relationship of thermomechanical effects to the current understanding of hydrologic processes in the unsaturated zone at Yucca Mountain is given in Section 6.4.1 of the SCP-CDR. Determination of the system performance goal (<1 m of relative motion of the rock) has been set by Issue 1.1 (total system performance, Section 8.3.5.13). If the goal does not adequately maintain the natural hydrologic processes at the site, then the potential exists to adversely affect system performance or releases to the accessible environment. This would most likely be associated with rock movement around the emplacement boreholes and drifts. Table 8.3.2.2-4 considers, as part of designing the thermal load, limiting the potential for deleterious rock movement and creating preferred pathways through controlling intact rock failure and continuous joint slip.

Limit surface impact

Temperature change and uplift are the plausible effects of the repository that may be detectable at the ground surface above the underground facility. A limit on the temperature change at the surface of 6 degrees Celsius has been selected. The performance goal for surface uplift, namely, that it should be comparable with natural analogues, is set so an analogy to naturally occurring rates of surface erosion can be made.

Limit near-field temperature changes

The temperature in the vicinity of the waste package is controllable, because it is dependent upon individual canister power generation and spacing and on overall thermal loading (areal power density (APD)). The spacing and APD, which are in turn functions of the emplacement borehole spacing and the

emplacement drift spacing, will be selected to satisfy the performance goals identified in Table 8.3.2.2-4.

For the immediate vicinity of the container, two performance goals are specified. These are the peak emplacement borehole wall rock temperature, which should be less than 275°C if the peak temperature criterion for the waste form is to be met (see also Issue 1.10, Section 8.3.4.2), and the volumetric limit on temperature rise, which ensures the design of the facility does not exceed the limits of properties measured. These goals are to be met subject to the additional constraint that the containers should be sufficiently hot, for the first 300 yr after emplacement, that the borehole walls should remain substantially dry. This constraint derives from a goal, defined under Issue 1.10, that the corrosiveness of the container environment be limited by ensuring that the containers remain dry.

Limit potential for borehole collapse

During the postclosure period, primary concern rests with the integrity of the waste package. The waste package is being designed considering loads during the preclosure and postclosure periods (Issue 1.10). The provisions for assurance that the design basis is not exceeded are discussed under function 1 and include skipping and isolating and locally adjusting the thermal load in regions that do not meet performance criteria. Such adjustments must be within the range of effects considered in the NRC license. If such measures do not adequately isolate the ground not meeting those criteria, then the potential exists for breaching containment. This would most likely be associated with rock movement around the emplacement boreholes. If the effects of such disturbances do not result in excessive loads on the waste package, this will not impact the ability of the repository to meet performance criteria.

Limit corrosiveness of container environment

This process is not derived directly from 10 CFR 60.133. Instead, it is a requirement placed on underground facility design by waste package design (Issue 1.10). The rationale for this requirement is discussed under that issue.

Interrelationships of the information needs

The seven information needs under this issue are

Information need	Subject
1.11.1	Site characterization information needed for design (Section 8.3.2.2.1)
1.11.2	Characteristics of waste package needed for design of the underground facility (Section 8.3.2.2.2)

Information need	Subject
1.11.3	Design concepts for orientation, geometry, layout, and depth of the underground facility that contribute to waste containment and isolation including flexibility to accommodate site specific conditions (Section 8.3.2.2.3)
1.11.4	Design constraints to limit water usage and potential chemical changes (Section 8.3.2.2.4)
1.11.5	Design constraints to limit excavation-induced changes in rock mass permeability (Section 8.3.2.2.5)
1.11.6	Repository thermal loading and predicted thermal and thermomechanical response of the host rock (Section 8.3.2.2.6)
1.11.7	Reference postclosure repository designs (Section 8.3.2.2.7)

As is shown on Figure 8.3.2.2-2, there is a direct relationship between the logic for issue resolution shown on Figure 8.3.2.2-1 and the information needs because the information needs were derived from what must be done for this issue to demonstrate compliance with 10 CFR 60.133. The information needs can be categorized as follows:

1. The first two (Information Needs 1.11.1 and 1.11.2) are collections of the information needed to resolve this issue and hence are closely related to the "parameter" step of performance allocation (Figure 8.3.2.2-2).

2. The next four (Information Needs 1.11.3 through 1.11.6) correspond to an issue resolution function of this issue (Figure 8.3.2.2-2).

3. The last (Information Need 1.11.7) is a summary of design information that will be provided by this issue to resolve performance assessment issues.

Data and analytical requirements for this issue are discussed in detail under the information needs. The data required to resolve this issue basically fall into one of three categories: (1) information from other issues, (2) site geologic data, and (3) rock properties data. The last two are discussed under the first information need in Section 8.3.2.2.1.

The first information need is satisfied by compiling all the site data requirements identified by Information Needs 1.11.3 through 1.11.6, addressing the question of how well these data need to be known and passing it to the site characterization issues.

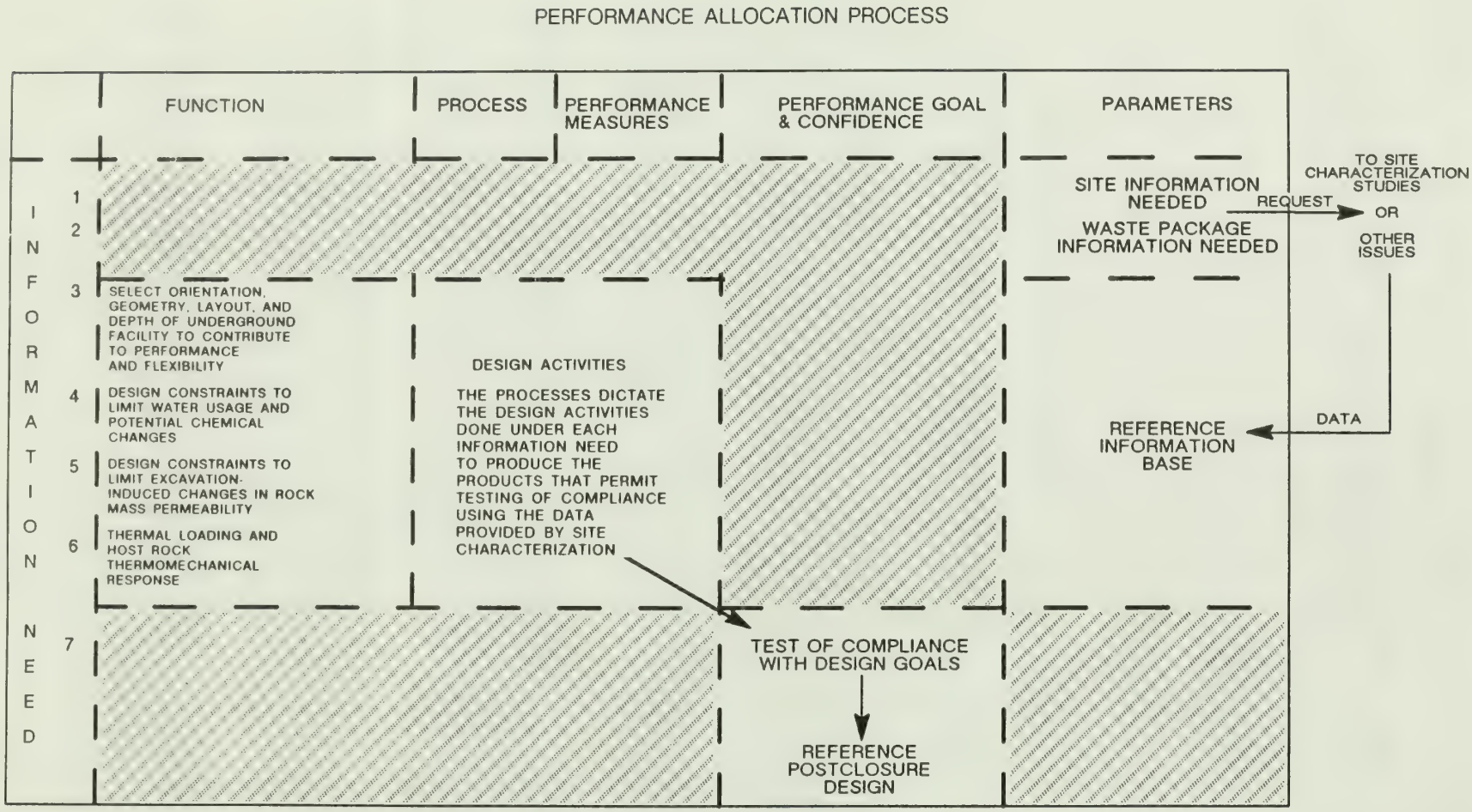


Figure 8.3.2.2-2. Relationship between subsumed information needs and issue functions and parameters for Issue 1.11, configuration of underground facilities (postclosure)

The second information need (similar to the first) compiles a list of waste package data needed to resolve this issue. This information need interfaces with Issue 1.10 (waste package characteristics (postclosure)).

Information Needs 1.11.3 through 1.11.6 discuss (1) the approaches (design activities) that will be used to ensure that performance goals are met with the appropriate level of confidence and (2) the data required by these approaches. The analytic techniques required to resolve this issue fall into one of two types: (1) the interactive graphics model or (2) geomechanical models. The first of these types is discussed in Information Need 1.11.3 and the second in Information Need 1.11.6.

The final information need under this issue documents the reference postclosure design and thereby provides the basis for satisfying Part b (provide information to support resolution of the performance issues) of the Issue (1.11).

The schedule information for Issue 1.11 (configuration of underground facilities) is presented in Section 8.3.2.2.8.

8.3.2.2.1 Information Need 1.11.1: Site characterization information needed for design

This information need does not correspond to an issue resolution function identified in the approach to resolving the issue discussion under Section 8.3.2.2. Rather, it summarizes the data requirements of other information needs of this issue and transmits these data requirements to the appropriate site characterization issues. This information need receives the experimental data from the characterization issues and then these data are properly converted from site measurements into reference information base (RIB) values that can be used by the other information needs of this issue and other issues. This information need will be satisfied by the following three products:

1. Data requirements list--identify site data needed from characterization issues (including how well data is needed to be known) to design the underground facility to contribute to containment and isolation.

2. Reference thermal/mechanical stratigraphy--document the three-dimensional thermal and mechanical stratigraphy of Yucca Mountain as contained in the interactive graphics information system as the reference basis for design and performance assessment.

3. Reference thermomechanical rock properties--conversion of measured data to reference data and transmission to the RIB for rock properties required by this issue.

Technical basis for addressing the information need

In the following subsections a link is established between this information need and the SCP technical data chapters and supporting documents. Specific site characterization parameters and the logic used in identifying how well they need to be known for resolution of this issue (1.11) are identified in this information need. Technical details of why a specific data item is needed are documented in the information need that identifies the input item. Where appropriate, the means of obtaining those parameters is then addressed.

Link to the technical data chapters and applicable support documents

Existing design activities and results, which are the basis for the approaches proposed in the logic subsection, are discussed in Section 6.4.2 of this document and in Chapters 7 and 8 of the Site Characterization Plan-Conceptual Design Report (SCP-CDR) (SNL, 1987). The current design data base used in existing design activities and used for comparison to the data needs given in the parameters subsection is given in SCP Section 6.1.2. A more complete discussion of current data is found in Chapter 2 for site data and in Chapter 7 for waste package data. Test plans for gathering additional site data needed by this issue (1.11) can be found under the rock characteristics program (Section 8.3.1.4), the thermal and mechanical properties program (Section 8.3.1.15), the geohydrology program (Section 8.3.1.2), the geochemistry program (Section 8.3.1.3), the postclosure and preclosure tectonics programs (Section 8.3.1.8 and 8.3.1.17), and the climate program (Section 8.3.1.5).

Parameters

Data needs given in this section are listed by the performance allocation function and performance goal for which they are required. The rationale behind the required site data is given in the subsequent logic section and in the individual information needs. The data required are numbered by the function number followed by a dash and the goal letter. For example, 4-W indicates a data need for function "4" to satisfy goal "W." Where appropriate the data needs of individual functions and goals are grouped.

The data required for the design activities that determine if the goals of this issue are met are given in Table 8.3.2.2-5.

Logic

Inputs received from the other information needs of Issue 1.11 are used to compile an integrated list of site information and data to resolve this issue. The completeness of site information requirements needed to resolve Issue 1.11 will be checked by reviewing its processes and goals and by identifying the interactions and response of the site to the design (e.g., site-specific effects of excavation and release of heat by the waste); once the response of Yucca Mountain to the design is adequately described using site-specific data, the site information items needed to resolve this interaction will be deemed complete.

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 1 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
1-A	Layout	Drawing of underground facility location	Dimensions accurate to ±3 m	Medium	Dimensions accurate to ±0.5 m[e]	Medium	8.3.2.5
	Topography	Contour map of primary area and extensions	Contours accurate to ±7.5 m	Medium	Contours accurate to ±3 m	Medium	8.3.1.14
		Contour map of areas with minimum overburden	Contours accurate to ±3 m	High	Contours accurate to ±3 m	Medium	8.3.1.14
	Elevation of unit contacts for positioning underground facility[f]	Structure contour maps on upper and lower contact of TSw2 in primary area and extensions	Contours accurate to ±30 m	Medium	Contours accurate to ±30 m	Low	8.3.1.4
		Structure contour map on lower contact of TSw2 in areas of minimum overburden	Contours accurate to ±10 m	High	Contours accurate to ±10 m[e]	Low	8.3.1.4
		Structure contour map on upper contact of TSw2 in areas of minimum ground-water travel time	Contours accurate to ±10 m	Medium	Contours accurate to ±10 m[e]	Low	8.3.1.4
	Water table elevation	Contour map of water table in primary area and extensions	Contours accurate to ±7.5 m	Medium	Contours accurate to ±7.5 m[e]	Medium	8.3.1.2

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 2 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed	Expected value	Current confidence	Obtained from SCP section
1-A (continued)		Contour map of water table in areas with minimum ground-water travel time	Contours accurate to ±10 m	High	Contours accurate to ±10 m[e]	Medium	8.3.1.2
	Fault descriptions for positioning underground facility	Map of fault locations showing dip and displacement for primary area and extensions	Locations accurate to ±30 m[g]	High	Locations accurate to ±30 m	Medium	8.3.1.4
			Actual strike and dip ±10° for each fault	High	Average strike and dip ±10° for each fault[e]	Medium	8.3.1.4
			Displacement measurements accurate to ±2 m	Medium	Displacement measurements accurate to ±2 m[e]	Low	8.3.1.4
		Classification	Standard practice	Low	Standard practice	Low	8.3.1.4
		Recurrence time for 5 cm displacement	>1,000 yr	High	(h)	Low	8.3.1.8
	Exploratory borehole locations	Coordinates of position of boreholes	Coordinates accurate to ±3 m	High	Coordinates accurate to ±1 m[e]	Medium	8.3.3.2
1-B	Goals of Issues 1.1, 1.6, and 1.10	Performance objectives affected by emplacement borehole design	See Issues 1.1, 1.6, and 1.10	Not applicable	Not applicable	Not applicable	8.3.5.13, 8.3.2.12, 8.3.4.2
1-C	Hydrothermal model describing how moisture moves in host rock	Data of Issue 1.1	See Issue 1.1	High	(h)	Low	8.3.5.13

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 3 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
1-D	Results of rock mass classification work of Issue 4.4	Identification of acceptable rock mass classifications	See Issue 4.4	High	See Issue 4.4	Low	8.3.2.5
1-E 1-F	Saturation	During development around the excavations	<90%	High	65 to 85%	Low	8.3.1.2, 8.3.5.16
	Geochemistry	During development around the excavations	See Issue 1.10	Medium	See Issue 1.10	Low	8.3.1.3, 8.3.5.16
1-G	See function 4 for data required	Goal 1-G requires results of thermal calculations of function 4. Hence, data required (heat capacity, initial temperature, container output, etc.) are called for under that issue.					8.3.2.2
1-H	See function 4 for data required	Goal 1-H requires results of thermal calculations of function 4. Hence, data required (thermal properties, initial stress, strength, etc.) are called for under that issue.					8.3.2.2
2-I	Material inventory	Proposed inventory	See Issue 4.4	High	(h)	Low	8.3.2.5
	Geochemical effects	Effect of inventory	(i)	Medium	(h)	Low	8.3.4.2
2-J	Planned water usage	For mining operations	See Issue 4.4	High	(h)	Low	8.3.2.5
	Water usage in ESF	For mining operations	See Section 8.3.1.2	Medium	(h)	Low	8.3.1.2

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 4 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
	Goals of Issue 1.1	Allowable saturations	See Section 8.3.5.13	Medium	Not applicable	Not applicable	8.3.5.13
3-K	Excavation method	Proposed method	See Issue 4.4	Medium	See Issue 4.4	Medium	8.3.2.5
	Disturbed zone	Definition	See Section 8.3.5.12	Medium	Not applicable	Not applicable	8.3.5.12
	Blast-induced permeability change	Around excavations	±50% of in situ permeability	Medium	(h)	Low	8.3.1.15
3-L	Layout	Drawings of layout of underground facility	Dimensions accurate to ±0.5 m	High	Dimensions accurate to ±0.5 m	Medium	8.3.2.5
3-M	Layout	Excavation dimensions	Dimensions accurate to ±0.5 m	High	Dimensions accurate to ±0.5 m	Medium	8.3.2.5
3-N	Proposed backfill	Height of fill	Nonsite data	Medium	Nonsite data	NA	8.3.2.5
4-W	Peak ground acceleration from probability versus ground motion	For TSw2 in primary area and extensions	0.5 to 0.7g with >10,000-yr return period	Medium	(h)	Low	8.3.1.17
4-X 4-T 4-O 4-P 4-Q 4-R 4-S	Topography	Contour map of location of ground surface in primary area and extensions for use in thermal modeling	Contours accurate to ±30 m	Medium	Contours accurate to ±30 m	Medium	8.3.1.4

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 5 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
4-X 4-T 4-O 4-P 4-Q 4-R 4-S	Geologic structure to water table (location of faults for thermal modeling)	Map of location of faults in primary area and extensions for use in thermal modeling	Location accurate to ±150 m	Medium	Location accurate to ±150m[e]	Low	8.3.1.4
4-X 4-T 4-O 4-P 4-Q 4-R 4-S	Geologic stratigraphy to water table (location of unit contacts for thermal modeling)	Structure contour maps on upper and lower contacts of TSw2 in primary area and extensions	Contours accurate to ±30 m	Medium	Contours accurate to ±30 m	Low	8.3.1.4
		Structure contour map on lower contact of TSw2 in areas with minimum overburden	Contours accurate to ±10 m	Medium	Contours accurate to ±10 m[e]	Low	8.3.1.4
		Structure contour map on upper contact of TSw2 in areas with minimum ground-water travel time	Contours accurate to ±10 m	Medium	Contours accurate to ±10 m[e]	Low	8.3.1.4
		Structure contour map on upper and lower contacts of other units in primary area and extensions	Contours accurate to ±60 m	Medium	Contours accurate to ±60 m[e]	Low	8.3.1.4

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 6 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
4-U 4-V 4-W 4-X	Emplacement geometry	Drawing locating boreholes and containers	Dimensions accurate to ±30 cm	High	Dimensions accurate to ±30 cm	Medium	8.3.2.5
		Drawing locating drifts	Dimensions accurate to ±3 m	Medium	Dimensions accurate to ±3 m	Medium	8.3.2.5
4-U 4-S 4-V 4-X	Container thermal output	Thermal output as a function of waste age and burnup	Nonsite data[j,k]	Not applicable	Nonsite data	Not applicable	8.3.4.2
4-W 4-O 4-P 4-Q	Container dimensions	(k)	Nonsite data[k]	Not applicable	Nonsite data	Not applicable	8.3.4.2
4-T 4-R	Waste inventory	(k)	Nonsite data[k]	Not applicable	Nonsite data	Not applicable	8.3.4.2
4-U 4-S 4-V 4-X	Initial temperature for thermal modeling	Of TSw2 in primary area and extensions	Temperature accurate to ±3°C[l]	Medium	Temperature = 23°C to 26°C ± 1.5°C[e]	Medium	8.3.1.15
4-W 4-O 4-P 4-Q 4-T 4-R		Mean annual air temperature for primary area	Temperature accurate to ±3°C	Medium	Temperature = 16°C to ±1°C[e]	Medium	8.3.1.12
4-W 4-Q 4-S	Initial stress state for primary area and extensions	Vertical stress and magnitude and direction of minimum and maximum horizontal stress	Vertical stress[m] accurate to ± 1 MPa	Medium	Vertical stress = weight of overburden	Low to medium	8.3.1.15

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 7 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
			Horizontal stress[m] accurate to ±2 MPa	Low	Horizonal/vertical stress ratio = 0.3 to 1 for TSw2	Low	8.3.1.15
4-U 4-S 4-V	Heat capacity	TSw2[n] <275°C	Current mean[o] ±10%	High	See Table 6-16	Low to medium	8.3.1.15
4-X 4-W 4-O		TSw3 and CHn1[n] <115°C	Current mean[o] ±10%	Medium	See Table 6-16	Low to medium	8.3.1.15
4-P 4-Q		Below CHn1[P] <100°C	Current mean[o] ±10%	Low	See Table 6-16	Low	8.3.1.15
4-T 4-R		TSw1[n] <275°C	Current mean[o] ±10%	Medium	See Table 6-16	Low to medium	8.3.1.15
		Above TSw1[P] <50°C	Current mean[o] ±10%	Low	See Table 6-16	Low	8.3.1.15
4-U 4-S 4-V	Thermal conductivity	TSw2[n] <275°C	Current mean[o] ±20%	High	See Table 6-16	Low to medium	8.3.1.15
4-X 4-W 4-O		TSw3 and CHn1[n] <115°C	Current mean[o] ±20%	Medium	See Table 6-16	Low to medium	8.3.1.15
4-P 4-Q 4-T		Below CHn1[P] <100°C	Current mean[o] ±20%	Low	See Table 6-16	Low to medium	8.3.1.15
4-R		TSw1[n] <275°C	Current mean[o] ±20%	Medium	See Table 6-16	Low to medium	8.3.1.15
		Above TSw1[P] <50°C	Current mean[o] ±20%	Low	See Table 6-16	Low to medium	8.3.1.15

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 8 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
4-W 4-Q 4-S	Coefficient of thermal expansion	TSw2 <275°C	Current mean[e] ±15%	High	See Table 6-16	Medium	8.3.1.15
		TSw3 and CHn1 <115°C	Current mean[e] ±15%	Medium	See Table 6-16	Low to medium	8.3.1.15
		Below CHn1 <100°C	Current mean[e] ±15%	Low	See Table 6-16	Low to medium	8.3.1.15
		TSw1 <275°C	Current mean[e] ±15%	Medium	See Table 6-16	Low to medium	8.3.1.15
		Above TSw1 <50°C	Current mean[e] ±15%	Low	See Table 6-16	Low to medium	8.3.1.15
4-W 4-Q 4-S	Young's modulus	TSw2 for 0-100 MPa	Current mean[e] ±15%	High	See Table 6-12	Medium	8.3.1.15
		TSw3 and CHn1[q]	Current mean[e] ±15%	Medium	See Table 6-12	Low	8.3.1.15
		Below CHn1[q]	Current mean[e] ±15%	Low	See Table 6-12	Low to medium	8.3.1.15
		TSw1 for 0-100 MPa	Current mean[e] ±15%	Medium	See Table 6-12	Medium	8.3.1.15
		Above TSw1[q]	Current mean[e] ±15%	Low	See Table 6-12	Low to medium	8.3.1.15
4-W 4-Q 4-S	Deformation modulus	TSw2 for 0-100 MPa	Current mean[e] ±15%	High	See Table 6-14	Low	8.3.1.15
		TSw3 and CHn1[q]	Current mean[e] ±15%	Medium	See Table 6-14	Low	8.3.1.15
		Below CHn1[q]	Current mean[e] ±15%	Low	See Table 6-14	Low	8.3.1.15
		TSw1 for 0-100 MPa	Current mean[e] ±15%	Medium	See Table 6-14	Low	8.3.1.15
		Above TSw1[q]	Current mean[e] ±15%	Low	See Table 6-14	Low	8.3.1.15

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 9 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
4-W 4-Q 4-S	Poisson's ratio	TSw2 for 0-100 MPa	Current mean[o] ±20%	Medium	See Table 6-12	Medium	8.3.1.15
		TSw3 and CHn1[q]	Current mean[o] ±20%	Low	See Table 6-12	Low to medium	8.3.1.15
		Below CHn1[q]	Current mean[o] ±20%	Low	See Table 6-12	Low to medium	8.3.1.15
		TSw1 for 0-100 MPa	Current mean[o] ±20%	Low	See Table 6-12	Low to medium	8.3.1.15
		Above TSw1[q]	Current mean[o] ±20%	Low	See Table 6-12	Low	8.3.1.15
4-W 4-Q 4-S	Matrix unconfined compressive strength for units other than TSw2 and TSw1	In situ conditions and representative strain rate[r]	Current mean[o] ±20%	Medium	See Table 6-12	Low to medium	8.3.1.15
4-W 4-Q 4-S	Matrix angle of internal friction for units other than TSw2 and TSw1	In situ conditions and representative strain rate[r]	Current mean[o] ±20%	Medium	See Table 6-12	Low to medium	8.3.1.15
4-W 4-Q 4-S	Matrix cohesion for units other than TSw2 and TSw1	In situ conditions and representative strain rate[r]	Current mean[o] ±20%	Medium	See Table 6-12	Low to medium	8.3.1.15

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 10 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
4-W 4-Q 4-S	Rock compressive strength for TSw1 and TSw2	0-100 MPa and representative strain rate[r]	Current mean[o] ±20%	High	(h)	Medium	8.3.1.15
4-W 4-Q 4-S	Joint angle of internal friction for units other than TSw2 and TSw1	In situ conditions and representative strain rate	Current mean[o] ±15%	Medium	See Table 6-13	Low	8.3.1.15
4-W 4-Q 4-S	Joint cohesion for units other than TSw2 and TSw1	In situ conditions and representative strain rate	Current mean[o] ±15%	Medium	See Table 6-13	Low	8.3.1.15
4-W 4-Q 4-S	Large-scale joint strength for TSw1 and TSw2	0-30 MPa normal stress and representative strain rate	Current mean[o] ±20%	High	(h)	Low	8.3.1.15
4-Q 4-W	Joint normal stiffness	TSw2	See Table 6-13[s]	Medium	See Table 6-13[t]	Low	8.3.1.15
		TSw1, TSw3, and CHn1	See Table 6-13[s]	Low	See Table 6-13[t]	Low	8.3.1.15
	Joint sheer stiffness	TSw2	See Table 6-13[s]	Medium	See Table 6-13[t]	Low	8.3.1.15
		TSw1, TSw3, and CHn1	See Table 6-13[s]	Low	See Table 6-13[t]	Low	8.3.1.15
	Joint spatial orientation	TSw2	See Table 6-15[s]	Medium	See Table 6-15	Low	8.3.1.4
		TSw1, TSw3, and CHn1	See Table 6-15[s]	Low	See Table 6-15	Low	8.3.1.4

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 11 of 12)

Related function and performance goal[b,c]	Performance parameter	Modifier	Tentative goal[d]	Needed confidence	Expected value	Current confidence	Obtained from SCP section
	Joint abundance	TSw2	See Table 6-15[e]	Medium	See Table 6-15	Low	8.3.1.4
		TSw1, TSw3, and CHn1	See Table 6-15[e]	Low	See Table 6-15	Low	8.3.1.4
	Joint persistence	TSw2	See Table 6-15[e]	Medium	See Table 6-15	Low	8.3.1.4
		TSw1, TSw3, and CHn1	See Table 6-15[e]	Low	See Table 6-15	Low	8.3.1.4
	Joint wall compressive strength	TSw2	See Table 6-15[e]	Medium	See Table 6-13	Low	8.3.1.15
		TSw1, TSw3, and CHn1	See Table 6-15[e]	Low	See Table 6-13	Low	8.3.1.15
	Joint roughness coefficient	TSw2	See Table 6-15[e]	Medium	See Table 6-13	Low	8.3.1.15
		TSw1, TSw3, and CHn1	See Table 6-15[e]	Low	See Table 6-13	Low	8.3.1.15

[a]Abbreviations used in this table are defined as follows: ESF = exploratory shaft facility; TSw1 = lithophysal portion of Topopah Spring welded unit; TSw2 = low lithophysal portion of Topopah Spring welded unit (preferred thermomechanical emplacement unit); TSw3 = basal vitrophyre Topopah Spring; CHn1 = tuffaceous beds of Calico Hills. See Chapter 2 for more complete description of units.

[b]Goals are ranked in judged order of importance of data item to issue resolution.

[c]1-A indicates function 1 and goal A. This designator is used to associate data requirements of this table with goals of Tables 8.3.2.2-1 through 8.3.2.2-4.

[d]Current mean is value given in current reference information (Tables 6-11 through 6-16).

[e]Expected value based on judgement.

[f]Elevation of the contacts of the thermal/mechanical unit TSw2 determined using data that already exists plus data to establish the top and bottom of unit TSw2 at the following approximate locations: (1) Midpoint of western ridge; (2) Northern extension of primary area: a) N775000 - E559000, b) N772500 - E560500, c) N773500 - E563500; and (3) Southeast extension of primary area: a) N760500 - E563000, b) N758500 - E561000, c) N757000 - E560000; and also by reevaluating existing borehole data: (1) Drill Hole Wash series; (2) H Hole series. Further lateral drifting from exploratory shaft will be used to (1) confirm contact between TSw1 and TSw2; (2) confirm fault locations at underground facility depth (for 2 or 3 faults, as intersected by lateral drifts); (3) confirm fault offsets in current structural model; and (4) provide drifting construction experience in faulted welded tuff.

Table 8.3.2.2-5. Performance parameters and tentative goals for Issue 1.11, configuration of underground facilities (postclosure)[a] (page 12 of 12)

Footnotes (continued)

[g]Averaged across the site, not accuracy at a given point.

[h]Inadequate information exists to establish expected value, but it is anticipated that a value satisfying the goal will be obtained.

[i]Accuracy determined by Issue 1.10 (Section 8.3.4.2).

[j]Calculations done to resolve this issue are based on power as a function of time (initial power and normalized decay function). As long as standard deviations of initial value and decay coefficients are no more than ten percent, calculations done to determine if goals of this issue are met should be valid.

[k]See Information Need 1.11.2 (Section 8.3.2.2.2) for details and accuracy.

[l]Existing data should be sufficient. Temperature could be a function of position in unit TSw2.

[m]Calculations are based on a vertical stress determined from the weight of the overburden and a horizontal to vertical stress ratio (K_o = 0.3 to 0.8). Calculations done to determine if the goals of this issue are met should be valid if the stresses so calculated are within the tentative goal specified for the in situ stress. Note: the tentative goal specified for the in situ stress is an estimate; if it can be shown with reasonable assurance that the minimum K_o is greater than 0.2, a lower accuracy for the tentative goal would be acceptable.

[n]Mean and standard deviation as a function of saturation.

[o]If the in situ rock at representative conditions has a distribution of property values which have the required confidences such that an adequate portion of the samples fall within the range prescribed by the current mean and percentage (percentage given in the table), then the calculations done to determine if the goals are met should be valid. If the distribution of property values does not meet this condition, then (1) the calculations will have to be reevaluated, (2) the calculations will have to be redone with new property values, (3) the design will have to be changed, (4) the accuracy of the data will have to be improved, or (5) the goal will not be met. Representative conditions are appropriate values of one or more of the following: saturation, stress, temperature, fracture, or jointing characteristics, etc., averaged over a representative volume.

[p]Mean and standard deviation representative at in situ saturation.

[q]At in situ conditions.

[r]Property representative of the volume of rock between dominate jointing.

[s]Sensitivity studies evaluating parameter range and goal have not yet been performed.

[t]These parameters can be calculated from values in Table 6-13.

In the subsequent discussion, the logic behind the data needs is organized by products.

The area-needed determination (product 1.11.3-1) depends on site data through the allowable areal power density. Information Need 1.11.6 (Section 8.3.2.2.6) discusses the site data related to that parameter.

The usable area and flexibility evaluation (product 1.11.3-2) requires the use of the interactive graphics information system (IGIS). Information Need 1.11.3 (Section 8.3.2.2.3) explains how these data contribute to the product. Data required for the use of the IGIS include

1. Stratigraphic data including strike, dip, thickness, and geographical location of distinct intervals (isopach data) and densities, orientations, and apertures of stratigraphically controlled fractures and lithophysae.

2. Structural data including locations, offsets, and widths of faults and fault zones; densities, orientations, and apertures of tectonic fractures.

3. Hydrologic model of Yucca Mountain including hydrologic flow paths, location of water table, and potential for perched water.

4. The potential for ground movement, which will be determined as described in Section 8.3.1.8.

How well the data that are input into this model need to be known has been determined by interactively using this model or by geometric figures representing the intersection of surfaces in this model to determine how much error in the data would result in a violation of the goal. For example, fault dips were varied to determine how much angular error in dip would result in unacceptable impacts on positioning of the underground facility and usable area.

The horizontal-versus-vertical emplacement decision (product 1.11.3-3) requires no site data beyond that required for the design of either mode (e.g., host rock physical and geomechanical properties, in situ principal stresses, fracture and fault geometry, and stratigraphy). This product draws on other issues (principally, Issue 4.4--preclosure design and technical feasibility) and depends on site data through those issues.

The drainage and moisture control plan (product 1.11.3-4) approach is still under development. For the design of the underground facility to contribute to waste containment and isolation, the drainage and moisture control plan will be based upon the performance assessment approach to system performance (Issue 1.1, Section 8.3.5.13). This performance assessment approach is still being documented. The approach to developing the drainage and moisture control plan is expected to apply basic engineering practice supplemented by simple thermal calculations (heat transfer by conduction) to identify regions of vaporization and condensation. This approach would require

the same site data as that used for Information Need 1.11.6 (8.3.2.2.6) of this issue. However, computer codes that model how moisture migrates through the host rock under hydrothermal conditions would be useful to verify that this approach is correct. These models are being developed for performance assessment (see Issues 1.1, total system performance (Section 8.3.5.13), and 1.4, containment by waste package (Section 8.3.5.9)), and the site data required for these models is identified as part of those issues.

The criteria for the contingency plan (product 1.11.3-5) approach is still under development. For the design of the underground facility to contribute to waste containment and isolation, the contingency plan must be based on the performance assessment approach to system performance (Issue 1.1, total system performance (Section 8.3.5.13), and take into account the functions of each system element (e.g., the disturbed zone). The criteria for the contingency plan will consider ground quality and saturation (Table 8.3.2.2-1). Ground quality will be determined by tunnel indexing methods discussed in Issue 4.4, technical feasibility (preclosure) (Section 8.3.2.5); the site data for those empirical engineering techniques are identified by that issue. The determination of the hydrologic processes important in the unsaturated zone at Yucca Mountain and the site data required to verify these processes are identified in Issue 1.4, containment by waste package (Section 8.3.5.9).

The material inventory criteria (product 1.11.4-1) and water usage criteria (product 1.11.4-2) do not depend directly on site; instead they depend on work for other issues. The Information Need 1.11.4 (Section 8.3.2.2.4) discusses these interfaces.

The extraction methods criteria (product 1.11.5-1) and long-term subsidence control strategy (product 1.11.5-2) require that the intrinsic permeability change be measured around the drifts to determine the extent of the blast-induced modified permeability zone. This requirement is needed to verify that the excavation technique (such as blast control) does not cause sufficient formation damage to extend the disturbed zone boundary. On the basis of Issue 1.6, ground-water travel time (Section 8.3.5.12), an order-of-magnitude permeability change and a factor-of-two porosity change have been chosen as significant. To satisfy the design performance goals, the permeability change beyond 75 percent of the distance to the boundary of the disturbed zone should be less than one order of magnitude (Section 8.3.5.12).

Thermal and thermomechanical modeling requires the following products:

1.11.6-1 Allowable areal power density.
1.11.6-2 Borehole spacing strategy.
1.11.6-3 Sensitivity studies.
1.11.6-4 Strategy for containment enhancement.
1.11.6-5 Reference calculations.

How well the data for thermal and thermomechanical modeling need to be known has been determined in a preliminary fashion by combining scoping sensitivity studies (included in Appendix N of the SCP-CDR (SNL, 1987)) and judgment. Properly controlled and documented sensitivity studies have been

completed for the near-field (Ehgartner, 1987). When corresponding far-field work is completed, how well these data need to be known will be reviewed and possibly revised.

These sensitivity studies have evaluated the system response (temperature, stress, deformation, and factor of safety) to one standard deviation changes in model input parameters. By comparing system response to goals or failure criteria (unconfined compressive strength), the model input parameter value that results in unacceptable system performance was determined. Engineering judgment was then used to choose the acceptable range and confidence for each parameter.

Data are required to validate the models; however, that activity is conducted by Issue 4.4 (Section 8.3.2.5) and the validated models made available to this issue. Hence, this issue does not call for data to validate models.

8.3.2.2.1.1 Design Activity 1.11.1.1: Compile a comprehensive list of all the information required from site characterization to resolve this issue

Objectives

This activity summarizes in one place all the information requirements needed to resolve this issue. These requirements are given in the logic section of this information need. Subsequent revisions will include applicable statistical requirements for each item (e.g., acceptable error and level of uncertainty).

8.3.2.2.1.2 Design Activity 1.11.1.2: Determine adequacy of existing site data

Objectives

If existing site data are not sufficient for licensing, a determination will be made whether additional site data should be gathered or changes be made in design to accommodate the existing data base. This activity will use statistical methods to evaluate site data and compare them to data requirements. Based on the results, recommendations for further data acquisition or trade-off studies to determine if the underground facility should be redesigned to accommodate the updated data base will be made.

8.3.2.2.1.3 Design Activity 1.11.1.3: Document reference three-dimensional thermal/mechanical stratigraphy of Yucca Mountain

Objectives

Topical reports will be produced that describe the three-dimensional thermal and mechanical stratigraphy of Yucca Mountain. The description will rely on data collected from the site that will be analyzed using the interactive graphics information system (IGIS) and be recorded in the reference information base (RIB) to be used for subsequent analyses and studies.

8.3.2.2.1.4 Design Activity 1.11.1.4: Preparation of reference properties for the reference information base

Objectives

Topical reports will be produced giving properties and describing how these were determined from field and lab measurements. These reports will be compared to the requirements of this issue to assure the RIB contains the required data. This work includes rock characteristics, initial conditions (in situ stress and temperature), geology (stratigraphy and structure as reported in the three-dimensional graphics model of Yucca Mountain), and design data (e.g., areal power density and borehole spacing).

8.3.2.2.1.5 Application of results

Three products result from this information need. The first product is a tabulation of required site data. This product will be used by selected site characterization issues to guide site characterization testing to acquire the necessary site data.

The second product will be documentation of the reference site thermal/mechanical stratigraphy. This product will result from analysis of site data acquired from the site characterization issues (principally Issue 1.15, rock characteristics (postclosure) (Section 8.3.1.4)) in response to the first product. This product will be incorporated in the Yucca Mountain Project reference information base for use in subsequent Project design and performance analyses. In particular, Information Need 1.11.3 (Section 8.3.2.2.3) will be a principal user of this product.

Finally, the third product will be a report defining the reference rock properties for postclosure design and performance. These properties will be derived from the data acquired under site characterization programs, principally the thermal and mechanical properties program (Section 8.3.1.15). The reference rock properties will be incorporated in the Yucca Mountain Project reference information base for use in subsequent Project design and performance analyses. In particular, Information Need 1.11.6 (Section 8.3.2.2.6) will be a principal user of this product.

8.3.2.2.2 Information Need 1.11.2: Characteristics of waste package needed for design of the underground facility

This information need exists

1. To identify waste package information items needed in the reference information base by this issue (1.11).

2. To design the underground facility to contribute to containment and isolation and thus contribute to the resolution of this issue and Key Issue 1 (postclosure performance).

3. To decide how well each waste package input item needs to be known to provide reasonable assurance of compliance with any regulation addressed by this information need.

The waste package information stipulated in this information need is not provided by site characterization. The information is identified here because it (1) has a major impact on design of the underground facility and (2) is a major stimulus affecting the long-term response of the repository. These factors combine to make waste package characteristics a key element in the resolution of this issue.

This information need does not correspond to an issue resolution function identified in the overview of this section (8.3.2.2). Rather, the data needs summarized in this information need are derived from the approaches to satisfying the goals of the other information needs of this issue. This information need will be satisfied by the following product:

1.11.2-1 Waste package characteristics for design of underground facility.

These data will be obtained from Issue 1.10 (Section 8.3.4.2) and recorded in the subsystem design requirements document.

Technical basis for addressing the information need

In the following subsections, a link is established between this information need and the SCP technical data chapters and supporting documents. Specific waste package parameters and the logic used in identifying how well they need to be known for resolution of this issue (1.11) (Section 8.3.2.2) are identified in this information need. Technical details of why a specific data item is needed are documented in the information need that identifies the information item. Where appropriate, the means of obtaining those parameters is then addressed.

Link to the technical data chapters and applicable support documents

Existing design activities, which are the bases for the needed waste package data items identified in the subsequent logic subsection, are discussed in the SCP Sections 6.3 and 6.4 and in Chapters 3, 4, and 8 of the Site Characterization Plan-Conceptual Design Report (SCP-CDR) (SNL, 1987). The current design data base, used in existing activities and for comparison

to the data needs given in the parameters section, is given in SCP Section 6.1.2 and SCP-CDR Chapter 2. A complete discussion of current waste package data is found in SCP Chapter 7. The waste package data needed by this issue will be defined and transmitted to the reference information base by Issue 1.10, waste package characteristics (postclosure) (Section 8.3.4.2).

Parameters

The following waste package characteristics will be needed to resolve this issue (1.11):

Waste or waste package characteristics	Specific information needed	Accuracy or range
Thermal decay characteristics	Waste type	Not applicable
	Waste age	±1 yr
	Thermal power output as a function of burnup	±10 % for 0 to 5,000 yr after reactor
Waste package size	Length, overall	±1%
	Diameter	±1%
Waste package temperature constraints	Maximum allowable temperature of waste package surface	±1°C
Waste inventory	Metric tons uranium (MTU) per waste type	±5%
	MTU per assembly or container as a function of enrichment	±5%
	Receipt schedule (MTU each year by wastage and burnup)	Age ±1 yr Burnup ±5,000 MWd

Logic

Like Information Need 1.11.1, inputs received from the other information needs of this issue are used to compile an integrated list of waste package input items to resolve Issue 1.11. The completeness of input items needed to resolve this issue will be checked by reviewing the processes and goals of this issue and by identifying the interactions and predicted response of the site to the design (e.g., site-specific effects of excavation and release of heat by the waste). Once the response of Yucca Mountain to the design is adequately described, the waste package information items needed to resolve this interaction will be deemed complete.

The thermal decay characteristics of the waste affect the allowed areal power density for waste emplacement, the host rock thermal response, and the

placement of the waste. This information is needed as a function of waste type, age, and burnup to

1. Determine the total area required for the projected waste inventory and to develop the layouts for the underground waste emplacement area (Information Need 1.11.3, Section 8.3.2.2.3). The use of current information and status in resolving Issue 1.11 is described in Section 6.4.2.

2. Predict the thermal response of the host rock (Information Need 1.11.6, Section 8.3.2.2.6) for use in establishing the areal power density and borehole spacing. This prediction will depend on the time-dependent power output of the waste.

3. Calculate thermal history of the rock mass for input into analysis codes used for long-term opening stability analysis. The status of opening stability analysis is described in Section 6.4.2.

Waste package size will be needed to define the emplacement envelope and thermal loading of the host rock and to design the boreholes (Information Need 1.11.3).

Waste package temperature limits will be needed to determine the emplacement borehole spacing. Spacing determined by consideration of waste package temperature will be used to develop the underground repository layout. These temperature limits will be used to perform the analysis for resolution of Information Needs 1.11.3, design concepts for orientation, geometry, layout, and depth of the underground facility that contribute to waste containment and isolation, including flexibility to accommodate site-specific conditions, and 1.11.6, repository thermal loading and predicted thermal and thermomechanical response of host rock. The methods for using this information to address these information needs are discussed in Chapter 6.

The following methods will be used to determine this information:

1. The thermal decay and thermal output of the waste will be calculated using codes like the Oak Ridge ORIGEN2 code, which is an isotope generation code that follows the decay chain of each specimen produced in the fission of uranium. This information will be used to define the specific decay and thermal characteristics for all waste types. Calculations will include the effect of fuel burnup.

2. The information needs pertaining to the waste package size and design will be based on the waste package functional criteria.

3. Waste package temperature will be limited by the maximum fuel-cladding temperature of spent fuel and the temperature of devitrification in defense high-level waste (DHLW).

8.3.2.2.2.1 Design Activity 1.11.2.1: Compile waste package information needed for repository design

Objectives

The objective of this activity is to determine what waste package information is needed for design of underground facility, obtain such data from Issue 1.10 (Section 8.3.4.2), and document it in the repository design requirements document.

8.3.2.2.2.2 Application of results

The information resulting from the resolution of Information Need 1.11.2 will be used to design the underground facility (specifically, Information Need 1.11.6 (Section 8.3.2.2.6)). Aspects of the underground design affected are opening size and shape, emplacement borehole spacing and depth, and the repository total area including contingency requirements.

8.3.2.2.3 Information Need 1.11.3: Design concepts for orientation, geometry, layout, and depth of the underground facility that contribute to waste containment and isolation including flexibility to accommodate site-specific conditions

The discussion under this information need extends the discussion of function 1, which was presented in the issue resolution strategy section for this issue (1.11). The approaches or methods to be used to calculate or otherwise establish that the anticipated or actual performance will meet the performance goals stated in Table 8.3.2.2-1 are described here. In many instances, the approaches, which follow in the logic section, require site data, performance information, or design information to make such an evaluation. The site data needs of this information need (1.11.3) are identified in the following parameters subsection. These needs are passed to the site characterization programs. Performance and design information needs are also identified in the following parameters subsection. In many instances, these performance and design information needs are the results or conclusions of work that depends on site data. The call for such site data is in the issue where the work is done and is not repeated here.

Table 8.3.2.2-1 identified five processes as contributing to meeting function 1. Each of these processes was related to one or more performance measures and their associated performance goals and desired confidences. The approaches and data needs discussed here are an extension of the horizontal relationships evident in that table.

This information need will be satisfied through five products that will be used to demonstrate that the performance goals of function 1 have been met. The products are the results of the design activities performed under this information need. The relationship of the five products to the five processes of function 1 is shown in Table 8.3.2.2-6.

Table 8.3.2.2-6. Relationship of Information Need 1.11.3 products to the processes associated with function 1 given in Table 8.3.2.2-1

	Product	Process
1.11.3-1	Area needed determination	Vary depth, dip, orientation, and lateral extent of underground facility to provide host rock with favorable isolation characteristics
1.11.3-2	Usable area and flexibility evaluation	
1.11.3-3	Vertical or horizontal emplacement orientation decision	Select emplacement borehole orientation that limits potential adverse effects and considers retrievability
1.11.3-4	Drainage and moisture control	Limit the amount of water in contact with container to provide favorable containment and isolation environment
1.11.3-5	Criteria for contingency plan[a]	Skip and isolate unfavorable areas
		Adjust thermal load to accommodate local conditions

[a]Contingency plan will be developed in Issue 4.4, technical feasibility (Section 8.3.2.5). Criteria developed here will relate to postclosure performance (e.g., fault standoff and thermal load adjustments).

These products may be delivered to other information needs under this issue or under other design or performance issues. In the following logic section, the products are used to group the approach and methods that will be used to show that the goals of this issue are met. Products are the results of the design activities and milestones identified later in this section.

Technical basis for addressing the information need

In the following subsection, the information needed by planned approaches for demonstrating that goals are satisfied is linked to data already available and plans for future data gathering. Specific parameters and the logic used to identify their importance to the resolution of Information Need 1.11.3 are then identified in subsequent subsections. The accuracy with which the parameters must be obtained is discussed under Information Needs 1.11.1 and 1.11.2 (Sections 8.3.2.2.1 and 8.3.2.2.2) where the site and waste package data needed to resolve this issue are consolidated.

Link to the technical data chapters and applicable support documents

The current design data base that has been used for existing design activities, and for comparison with data needs given in the following parameters subsection, is presented in the reference design data base in Section 6.1.2. A more detailed discussion of the current data in the reference design data base may be found in the data Chapters 1 through 5, and current waste package data are found in Chapter 7.

Data needed to resolve this issue already available are presented in Section 6.4.2. Section 6.4.2 provides the status of resolution of Issue 1.11 and also forms some of the bases for the approaches discussed in the following logic subsection.

Finally, Information Need 1.11.1 (Section 8.3.2.2.1) lists in detail the site data needs established in this information need, as well as for all other information needs under this issue. It also defines how well they need to be known to resolve the issue and identifies the site characterization issues under which the test plans for obtaining each site date need will be discussed.

Parameters

Parameters are those data and other information items listed in this section in Table 8.3.2.2-7 that are required to complete the activities and analyses necessary to develop the products identified in Table 8.3.2.2-6. Those activities and analyses will establish that the goals defined in Table 8.3.2.2-1 are met with the required level of confidence. The logic for identification of the products as being necessary to satisfy the information need, as well as the basis for identification of specific parameters and information items, is provided by the following subsection.

Logic

The major purpose of this information need is to identify underground facility design options and related decisions important to containment and isolation, and to describe the approaches and methods to be used to develop the products that satisfy the information need. The logic used in developing these approaches and methods is described in this subsection, which also provides the basis for the needed site data and other information listed previously. Specific activities that will be performed are identified in the following material. If such activities have been initiated already, their status is discussed in Section 6.4.2.

To satisfy the information need, it is necessary to determine the area needed for disposal of the waste (product 1.11.3-1) and the usable area (product 1.11.3-2). The usable area product must consider the necessity of incorporating sufficient flexibility in the design to allow adjustments to accommodate specific site conditions that may be identified through in situ monitoring, testing, or excavation. Design concepts that contribute to performance and flexibility may be impacted by the decision between vertical and horizontal boreholes for waste emplacement (product 1.11.3-3); thus, this

Table 8.3.2.2-7. Parameters and information required to satisfy Information Need 1.11.3

	Product	Parameters and input items
1.11.3-1	Area needed determination	Geometrical requirements Minimum allowable spacing between emplacement boreholes for equipment operation (Issue 4.4, Section 8.3.2.5) Minimum allowable spacing between emplacement boreholes for meeting thermal response constraints (Information Need 1.11.6, Section 8.3.2.2.6) Waste handling equipment requirements placed on drift layout and design (Issue 4.4) Ventilation requirements placed on drift layout and design (Issue 4.4) Inventory of waste to be emplaced in the repository Total metric tons of uranium (MTU) and number of containers Thermal output per MTU as function of waste type, age, and burnup (Issue 1.10, Section 8.3.4.2) Sealing program requirements for underground layout (Issue 1.12, Section 8.3.3.2) Area requirements for nonwaste emplacement areas, including underground area for the exploratory shaft test facility (Issue 4.4) Typical panel layout, with borehole spacing and drift separations for all waste types, that will ensure waste and rock mass temperature criteria are met (Information Need 1.11.6) Allowable thermal loading of the underground facility (areal power density) by waste type (Information Need 1.11.6)
1.11.3-2	Usable area and flexibility evaluation	Site geologic data Stratigraphic data, including dip, thickness, and geographic locations of distinct intervals; densities, orientations, and apertures of stratigraphic controlled fractures and lithophysae

Table 8.3.2.2-7. Parameters and information required to satisfy Information Need 1.12.3 (continued)

Product		Parameters and input items
1.11.3-2	Usable area and flexibility evaluation (continued)	Structural data, including location, offsets, and widths of faults and fault zones; spatial frequencies, orientations, and apertures of tectonic fractures
		Hydrologic model of Yucca Mountain, including hydrologic flow paths, location of water table, and potential for perched water Topographic data
		Contingency plan for accommodating unsuitable areas for development and/or waste emplacement (Issue 4.4)
		Anticipated occurrence of conditions necessitating implementation of the contingency plan
1.11.3-3	Vertical vs. horizontal emplacement orientation decision	Performance criteria identified in Issues 1.4 (Section 8.3.5.9), 1.5 (Section 8.3.5.10), 1.10 (Section 8.3.4.2), and 2.4 (Section 8.3.5.2)
		Near-field thermomechanical analyses of boreholes and emplacement drifts (completed under Information Need 1.11.6)
		Results of field demonstrations of borehole construction methods (Issue 4.4)
		Total system performance assessment (Issue 1.1, Section 8.3.5.13)
1.11.3-4	Drainage and moisture control plan	Proposed panel layout, for alternate waste types characteristics
		Near-field thermal analyses of borehole (completed under Information Need 1.11.6)
		Criteria from Issues 1.1, 1.4, and 1.10
		Propose ventilation system for the repository, including distribution, flow rates, temperature, and moisture content (Issue 4.4)
		Total system performance assessment (Issue 1.1)

Table 8.3.2.2-7. Parameters and information required to satisfy Information Need 1.12.3 (continued)

Product		Parameters and input items
1.11.3-5	Criteria for contingency plan	Criteria for ground quality that will satisfy Issues 1.1, 1.10, and 1.12 (Section 8.3.3.2). Criteria for technical feasibility of construction (Issue 4.4) retrieval (Issue 2.4) Standoff distance from ground with unfavorable properties, as constrained by Issue 1.1 Thermal and thermomechanical analyses of excavations under normal and off-normal conditions (Information Need 1.11.6)

decision must be made to satisfy this information need. Water drainage control requirements may also impact the design concepts that contribute to performance and flexibility, so an evaluation of such requirements is necessary to satisfy this information need (product 1.11.3-4). Criteria that will be used to establish whether actual site conditions are consistent with the design bases, as well as the measures that will be taken to accommodate any such departures, are discussed in the contingency plan (product 1.11.3-5).

Product 1.11.3-1: Area needed determination

For the waste emplacement areas, the area needed is the total thermal output of the waste divided by the allowable thermal load. In turn, the total thermal output is determined from the inventory of waste to be disposed, including the thermal output per metric ton of uranium as a function of waste type, age, burnup, and enrichment.

At present, it is expected that the actual thermal output of individual waste packages may vary as much as one order of magnitude. Such variations will be dealt with on a local basis by possibly skipping some holes and, in the case of horizontal emplacement, flexibility in spacing of waste packages within an individual borehole. These adjustments would be made subject to other geometrical constraints, including such items as minimum spacing between boreholes to ensure proper shielding during emplacement and noninterference at borehole collars for the transporter. In addition, constraints imposed by retrieval, decommissioning, and performance requirements must also be accommodated.

A preliminary determination of the area requirement has been made (Mansure, 1985). Data needs identified in the parameters section are based upon the information actually used in that study.

Product 1.11.3-2: Usable area and flexibility evaluation

The usable area and amount of flexibility will be evaluated using an interactive graphics information system. This system uses a data base established from field data to produce a three-dimensional graphics model of Yucca Mountain. Displays of this model will then be used to identify areas of the mountain that satisfy all the performance goals identified in Table 8.3.2.2-1. Boundaries of the waste emplacement areas are thereby established. The boundaries are required to design a functional layout of the underground facilities and its relation with the surface facilities. Location of the waste emplacement area within the site permits a site-specific (location dependent) performance assessment of the underground facility to be undertaken.

A preliminary evaluation of subsurface waste emplacement areas and a preliminary location and shape for the underground facility has been determined (Mansure and Ortiz, 1984). Data needs identified in the parameters subsection are based upon the information used in that study.

Product 1.11.3-3: Vertical or horizontal emplacement orientation decision

Vertical emplacement uses boreholes drilled in the floor of the emplacement drifts, with one waste package placed in each borehole. This mode requires a relatively high mining extraction ratio compared to the horizontal emplacement mode. The design basis for horizontal emplacement boreholes allows multiple waste packages per borehole. Equipment development and proof-of-concept demonstrations for horizontal drilling and waste emplacement are described under Issue 4.4, technical feasibility (Section 8.3.2.5).

The selection of one of the two alternative emplacement modes will be based on performance considerations discussed under Information Need 1.11.6, (Section 8.3.2.2.6) as well as Issues 1.1, total system performance (Section 8.3.5.13), 1.10, waste package characteristics (postclosure) (Section 8.3.4.2), and 4.2, nonradiological health and safety (Section 8.3.2.4).

Product 1.11.3-4: Drainage and moisture control plan

The approach for meeting this goal is still under development since the approach to demonstrate performance by Issues 1.1, total system performance (Section 8.3.5.13) and 1.10, waste package characteristics (postclosure) (Section 8.3.4.2) is still being documented; however, it is expected that the approach of this information need will apply engineering practice supplemented with simple thermal calculations (heat transfer by conduction) to identify regions of vaporization and condensation so that the emplacement drifts and boreholes can be designed to control water migration. Seals will also be designed to control water migration (see Issue 1.12, Section 8.3.3.2). The system will be designed to promote the migration of moisture away from the containers.

Site data required to conduct these near-field thermal calculations are anticipated to be identical to the data required under Information Need 1.11.6 (Section 8.3.2.2.6) to calculate the thermomechanical response.

Product 1.11.3-5: Criteria for contingency plan

In siting and constructing shafts, ramps, drifts, or boreholes within Yucca Mountain, unexpected conditions such as small zones of perched water, localized heavy fractured zones, water recharge pathways, or localized heavily lithophysae-rich zones may be encountered. A contingency plan for the layout must be established to deal with these possibilities and to provide confidence that the repository, as constructed, will provide waste containment and isolation for the required repository capacity. The contingency plan must also establish the methods and related criteria that will be used to initiate its implementation. Administration of the contingency plan will be the responsibility of performance confirmation (Issue 1.7, performance confirmation (Section 8.3.5.16)).

Development of the contingency plan will begin with the assumption that all the target area will be considered acceptable, except for local regions identified as being unacceptable during the site characterization phase. Such known and similar anticipated regions will have been subtracted from the available area during the determination of the usable area, as discussed previously under product 1.11.3-2. An additional contingency will be provided to accommodate regions where specific local site conditions found during development of the underground facility are not within the ranges assumed in licensing review. The contingency plan will establish procedures to accommodate regions where specific site conditions are found to be off normal during development of the underground facility. The licensing of this plan will include the establishment of parameter ranges that will be used to decide what course of action will be implemented.

The repository design will be based on certain anticipated ranges of parameters and conditions. These ranges will be clearly defined for the licensing review. Since many of the parameters and conditions cannot be easily measured over the total site during site characterization, a set of simple procedures must be established for determining if the site conforms to the ranges defined in the licensing review. These procedures will have associated quantitative criteria to determine whether development can continue without modification. Failure to meet these criteria at any location would result in a requirement for more detailed evaluation of the condition encountered. If such evaluation indicates that local conditions are not consistent with meeting performance objectives and regulatory requirements using the baseline design, then design modifications would be required. The procedures for implementing such modifications would be licensed as part of the contingency plan, implemented by the performance confirmation program, and reported to and reviewed with NRC. These might include

1. Continued development but with design revisions such as increased ground support and reduced thermal loading.

2. Skipping and isolating an area unfavorable for development.

In this approach, parameters that describe site conditions encountered can be considered to be in one of three ranges: (1) the range for which the baseline design applies, (2) the range for which the contingency plan describes how modifications must be made to the design, or (3) the range that

falls outside that approved in licensing. It is the function of the contingency plan to reduce the potential for the last range resulting in adverse effects on isolation, containment, and cost.

That faults and other discontinuities will be encountered is implicit in the preceding discussion. By design, the major faults (e.g., Solitario Canyon fault) will be worked around. Minor faults and other discontinuities cannot all be avoided entirely and some will have to be crossed. Most are not expected to have undesirable characteristics and will not affect the repository design or layout; others may have associated characteristics that trigger implementation of the contingency measures such as those suggested previously.

Specific procedures for establishing the need to adopt contingency measures have not yet been defined. However, it is anticipated that extensive use will be made of existing empirical engineering procedures. For example, Rock Mass Quality Designation (Barton et al., 1974b) and Geomechanical Classification (Bieniawski, 1974) indices will be used to determine if the ground could be assigned an appropriate degree of ground support for preclosure operation. Based upon these indices, the ground support system may be changed or an area may be skipped. (Actual application of these tunnel indexing methods will be in Issue 4.4, technical feasibility (Section 8.3.2.5)). The postclosure implications of such actions, and other site conditions that might trigger remedial action, will be evaluated according to the criteria established in Issues 1.1, total system performance (Section 8.3.5.13) and 1.10, waste package characteristics (postclosure) (Section 8.3.4.2). This issue is concerned solely with ensuring that postclosure considerations are appropriately addressed in the contingency plan. This will involve establishing nonacceptance criteria and practical methods for identifying unacceptable conditions.

Development of the contingency plan requires that system performance of off-normal conditions be performed. Site data required to perform such assessments are the same as defined under product 1.11.3-1. In addition, a set of reasonable off-normal conditions that are consistent with the geologic setting need to be developed. These may be as simple as extreme variations on material properties, but may include extensive brecciated zones, large pockets of lithophysal material, and perched water tables.

However, it is anticipated that part of the contingency plan will consider the mechanical stability of the rock mass and will use existing, and later modified (to account for thermal loading and site-specific conditions), empirical engineering procedures to initially qualify the stability of underground openings.

8.3.2.2.3.1 Design Activity 1.11.3.1: Area needed determination

The objective of this activity is to determine the area required for the underground facility (product 1.11.3-1). This determination will be revised as input data change (particularly data on waste inventory and allowable thermal loading). The technical basis part of the previous section discusses

the approach for determining the area needed and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.3.2 Design Activity 1.11.3.2: Usable area and flexibility evaluation

The objectives of this activity are to

1. Analyze the three-dimensional structure and stratigraphy of Yucca Mountain to identify usable areas and ensure sufficient area is characterized to allow flexibility in design.

2. Produce graphic cross sections and maps that can be used to layout the drift arrangements.

3. Compare drift arrangements to ensure they fit the geology and structure.

4. Identify site geologic data requirements.

This work will result in a series of graphic products in the reference information base, inputs into the data requirements (Information Need 1.11.1, (Section 8.3.2.2.1)) and topical reports. The technical basis part of Section 8.3.2.2.3 discusses the approach for this evaluation and Section 8.3.2.2.1 discusses the data requirement for the activity.

8.3.2.2.3.3 Design Activity 1.11.3.3: Vertical and horizontal emplacement orientation decision

The objective of this activity is to provide the performance evaluation necessary to document this decision. The technical basis part of Section 8.3.2.2.3 discusses the approach to the orientation decision and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.3.4 Design Activity 1.11.3.4: Drainage and moisture control plan

The objective of this activity is to provide postclosure design requirements for the layout of the underground facility to be used in Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5). The design requirements will limit the amount of water in contact with the container so as to provide a favorable containment and isolation environment. The technical basis part of Section 8.3.2.2.1 discusses the approach to develop this plan and the models and data requirements for this plan.

8.3.2.2.3.5 Design Activity 1.11.3.5: Criteria for contingency plan

The objective of this activity is to provide criteria for the contingency plan developed by Issue 4.4, technical feasibility (Section 8.3.2.5). The technical basis part of Section 8.3.2.2.3 discusses the approach to developing the contingency plan and Section 8.3.2.2.1 gives the data requirements for this plan.

8.3.2.2.3.6 Application of results

The products and information developed under this information need (1.11.3) will be used as input to the reference postclosure repository design discussed in Section 8.3.2.2.7, Information Need 1.11.7. Products 1.11.3-4 and 1.11.3-5 (Activities 1.11.3.4 and 1.11.3.5) will become criteria for the preclosure design work done by Issue 4.4 (Section 8.3.2.5). The site parameters identified under this information need are conveyed to the site characterization programs by Information Need 1.11.1 (Section 8.3.2.2.1) along with details about how well the site data should be determined.

8.3.2.2.4 Information Need 1.11.4: Design constraints to limit water usage and potential chemical changes

The discussion under this information need extends the discussion of function 2, presented earlier in the issue resolution strategy section for the issue (1.11). The approaches or methods to be used to calculate or otherwise establish that the anticipated or actual performance will meet the performance goals stated in Table 8.3.2.2-2 are described here. In many instances, the approaches which follow in the logic subsection require site data, performance information, or design information to make such an evaluation. The site data needs of this information need (1.11.4) are identified in the following parameters section. These needs are passed to the site characterization programs. Performance and design information needs are also identified in the following parameters subsection. In many instances, the performance and design information needs are the results or conclusions of work that depends on site data. The call for such site data is in the issue where the work is done and is not repeated here.

Table 8.3.2.2-2 identified two processes necessary for meeting function 2. Each of these processes was related to one or more performance measures, and their associated performance goals and desired confidences. The approaches and data needs discussed here are an extension of the horizontal relationship evident in Table 8.3.2.2-2.

This information need will be satisfied through two products that will be used to demonstrate that the performance goals of function 2 have been met. The products are the results of the design activities performed under this information need. The relationship of the two products to the two processes of function 2 is shown in Table 8.3.2.2-8.

Table 8.3.2.2-8. Relationship of Information Need 1.11.4 products to the processes associated with function 2 (Table 8.3.2.2-2)

	Product	Process
1.11.4-1	Material inventory criteria (total quantity, type, and location within the repository)	Limit adverse chemical effects by using acceptable materials
1.11.4-2	Water usage criteria (total and individual requirements)	Limit the amount of water used in construction, operation, emplacement of seals, and decommissioning to provide favorable containment and isolation environment

These products will be delivered to other information needs under this issue, and to Issue 4.4, technical feasibility (Section 8.3.2.5) and Issue 1.1, total system performance (Section 8.3.5.13). In the following logic subsection, the products are used to group the approach and methods that will be used to show that the goals of this issue are met. Products are the results of the design activities and milestones identified later in this section.

Technical basis for addressing the information need

In the following subsection, the information needed by planned approaches for demonstrating that goals are satisfied is linked to data already available and to plans for future data gathering. Specific parameters and the logic used in identifying that they are important to resolution of Information Need 1.11.4 are then identified in subsequent subsections. The accuracy with which the parameters must be obtained is discussed under Information Needs 1.11.1 (Section 8.3.2.2.1) and 1.11.2 (Section 8.3.2.2.2) where the site and waste package data needed to resolve this issue are consolidated.

Link to the technical data chapters and applicable support documents

The current design data base that has been used for existing design activities and for comparison with data needs given in the following parameters subsection, is presented in the reference design data base Section 6.1.2. A more detailed discussion of the current data in the reference design data base may be found in the data Chapters 1 through 5, and current waste package data are found in Chapter 7.

The data needed to resolve this issue that are already available are presented in Section 6.4.2. Section 6.4.2 provides the status of resolution

of Issue 1.11 and also forms some of the bases for the approaches discussed under the logic subsection.

Finally, Information Need 1.11.1 (Section 8.3.2.2.1), lists in detail the site data needs established in this information need, as well as for all other information needs under Issue 1.11. That information need also defines how well they need to be known to resolve the issue and identifies the site characterization issues under which the test plans for obtaining each site data need will be discussed.

Parameters

Parameters listed in this subsection (Table 8.3.2.2-9) are those site data and other input items required to complete the activities and analyses necessary to develop the products that are identified in Table 8.3.2.2-8. Those activities and analyses will be performed so as to establish that the goals defined in Table 8.3.2.2-2 are met with the required level of confidence. The logic for identification of the products as being necessary to satisfy the information need, as well as the basis for identification of specific parameters and information items, is provided in the following subsection. For this particular information need none of the data identified in the table are site data.

Table 8.3.2.2-9. Parameters and information items required to satisfy Information Need 1.11.4

Product		Parameters and input items
1.11.4-1	Material inventory criteria	Inventory of materials to be introduced into the repository site (from Site Characterization Plan-Conceptual Design Report and Issue 4.4, Section 8.3.2.5)
		Waste package environment constraints (from Issue 1.10, Section 8.3.4.2)
		Total system performance analysis (from Issue 1.1, Section 8.3.5.13)
1.11.4-2	Water usage criteria	Planned water usage (from Issue 4.4)
		Waste package environment constraints (from Issue 1.10)
		Total system performance analysis (from Issue 1.1)

Logic

To satisfy the information need, two sets of criteria will be developed for use in control of the repository design, construction, operation, and closure. The first set of criteria concerns the modification of the post-closure geochemical environment of the waste package as a result of all pre-closure activities (product 1.11.4-1). The constraints on modification of that environment will be received from Issue 1.10 (Section 8.3.4.2) for waste package containment requirements and from Issue 1.1 (Section 8.3.5.13) for waste isolation requirements. The second set of criteria concerns changes in degree of saturation of the host rock as a result of all preclosure activities (product 1.11.4-2). Other criteria are established under Information Needs 1.11.3 and 1.11.5 (Sections 8.3.2.2.3 and 8.3.2.2.5).

Product 1.11.4-1: Material inventory criteria. Specific performance requirements are placed on the containment life of the waste packages. Design of a waste package that meets those performance requirements is based on assumptions regarding the geochemical environment to which it will be exposed during the preclosure and postclosure periods. Verification of the site performance, including any geochemical changes, is based on performance assessment analyses, requiring an accurate description of the chemistry of the host rock and the ground water. The extent to which the construction and operation of the repository will modify the geochemistry of the host rock and the ground water is, therefore, an important data need.

Issue 1.10, (Section 8.3.4.2) identifies changes in the pH and organic content of the ground water that might interact with the waste package, and influence containment and isolation. Further, Issue 1.10 specifies limits on these changes as constraints on the postclosure repository design. Potential causes of such changes have been identified, for example, as cement used for repository construction and operation (especially for the emplacement hole construction and preparation), in organic materials contained in any flushing medium during borehole construction (if the emplacement boreholes are not drilled dry as currently planned), shotcrete used for lining openings, and rock bolt anchor grouts or epoxies. Performance goals responsive to those concerns were set in Table 8.3.2.2-2. Repository design criteria and construction and operating procedures must be developed that will ensure all such goals are met.

Other changes to the geochemical environment, beyond those identified here, are identified in Issue 1.10, waste package characteristics (post-closure) (Section 8.3.4.2). Accordingly, the complete data need is identified as an inventory and distribution of all materials introduced into the site during repository construction and operation.

The responsibility of this information need is to establish design criteria for both the preclosure and postclosure periods based on the performance goals of Issues 1.1, total system performance (Section 8.3.5.13), and 1.10, waste package characteristics (postclosure) (Section 8.3.4.2). To do this (1) the potential impacts (pH changes, etc.) of a given quantity of materials must be assessed and (2) a plan must be developed to control the materials in the postclosure system so as to reasonably assure that performance goals will be met. The plan can meet the goals either by controlling the materials used during preclosure or by requiring the removal of materials

during decommissioning. The design criteria will be an input into the decommissioning plan to be developed by Information Need 4.4.9 (Section 8.3.2.5.9).

Total system performance (Issue 1.1) should then analyze the plan to ensure that the repository would meet all performance requirements, given the proposed design and corresponding modification of the geochemical environment. Methods to control the materials inventory during construction and operation of the facility will be defined as part of the repository design, under Issue 4.4.7 (Section 8.3.2.5.7).

Product 1.11.4-2: Water management criteria. The current design basis for the waste container is that the surface of the container should remain substantially dry for at least 300 yr after closure. Measures taken to ensure that the design basis will be met include (1) location of the repository in unsaturated host rock, (2) design of an underground layout that will enhance the drainage of any free water away from the containers, and (3) maintaining of a near-container temperature that will be sufficient to evaporate most free water. Drainage and evaporation, as means to control the amount of water to which the waste containers will be exposed, are discussed under Information Needs 1.11.3 (Section 8.3.2.2.3) and 1.11.6 (Section 8.3.2.2.6). Under this information need the potential for significantly changing the degree of saturation of the low lithophysal portion of the Topopah Spring Member unit during construction, operation, and closure of the repository is addressed.

The most probable source of a sufficient quantity of water to cause a long-term change in the degree of saturation of the low lithophysal portion of the Topopah Spring Member unit would be water used as a flushing medium during drilling of emplacement boreholes. Accordingly, the current design basis is that an air flushing system should be used for borehole drilling. The appropriateness of this approach will be evaluated considering such factors as cost, worker safety, and available technology.

As for the materials inventory discussed previously, the responsibility under this information need is to establish realistic design criteria that, if met, would ensure that the postclosure performance goals will be met. Such criteria should be developed through analyses that consider the expected interactions, including fluid penetration, changes in the saturation level, and chemical interactions between the flushing medium and the rock mass.

The method of drilling the emplacement boreholes is particularly important because of the direct connection to the container environment. The design basis for construction of the shafts, access drifts, and emplacement drifts is that conventional drill and blast or mechanical mining methods will be used. Appropriate amounts of water will be used during this construction for dust suppression. Measures for controlling the movement of such water through layout are discussed under Information Need 1.11.3 (Section 8.3.2.2.3). However, some water will enter the host rock. The quantity and distribution (e.g., points of application and method of application) of that water used in construction and operations will be investigated by this information need, and a water balance for the entire facility will be established. Associated operating procedures must then be developed to ensure that water entering the repository is managed appropriately. The

responsibility under this information need is to determine reasonable water usage amounts, to develop tentative criteria for the repository design, and to define the performance assessment analyses needed to demonstrate compliance with postclosure performance goals.

8.3.2.2.4.1 Design Activity 1.11.4.1: Chemical changes resulting from the use of construction materials

The objective of this activity is to quantify the chemical changes (e.g., change in pH) that result from the use of a given quantity of construction material (e.g., cement). The technical basis part of the previous section discusses the role of this activity in Information Need 1.11.4, and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.4.2 Design Activity 1.11.4.2: Material inventory criteria

The objective of this activity is to establish appropriate limits on the inventory of the materials that will be used in construction and operation of the underground facility and write criteria for the appropriate limits on the inventory of materials that will be left in the openings after decommissioning including backfill. The technical basis part of the previous section discusses the role of this activity in Information Need 1.11.4, and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.4.3 Design Activity 1.11.4.3: Water management criteria

The objective of this activity is to establish appropriate limits on the amount of water that will be used for underground facility construction and operation, indicating amounts and locations for individual operations, and to convey those limits to Issue 4.4 (Section 8.3.2.2.5). The technical basis part of Section 8.3.2.4 discusses the role of these criteria in resolving Information Need 1.11.4, and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.4.4 Application of results

This information will serve as input to the advanced conceptual design and license application design reports and in the reference postclosure design (Information Need 1.11.7, Section 8.3.2.2.7). The results of this information need will be criteria placed on the preclosure design process controlled by Issue 4.4 (Section 8.3.2.2.5). The results will be used in Issues 1.1, total system performance (Section 8.3.5.13) and 1.10, waste package characteristics (postclosure) (Section 8.3.4.2), as part of performance assessment.

8.3.2.2.5 Information Need 1.11.5: Design constraints to limit excavation-induced changes in rock mass permeability

The discussion under this information need extends the discussion of function 3, presented in the issue resolution strategy section for this issue (1.11). The approaches or methods to be used to calculate or otherwise establish that the anticipated or actual performance will meet the performance goals stated in Table 8.3.2.2-3 are described here. In many instances, the approaches, which follow in the logic section, require site data, performance information, or design information to make such an evaluation. The site data needs of this information need (1.11.5) are identified in the following parameters subsection. These needs are passed to the site characterization programs. Performance and design information needs are also identified in the following parameters subsection. In many instances, these performance and design information needs are the results or conclusions of work that depends on site data. The call for such data is in the issue where the work is done and is not repeated here.

Table 8.3.2.2-3 identified two processes as contributing to meeting function 3. Both of these processes were related to one or more performance measures and their associated performance goals and desired confidences. The approaches and data needs discussed are an extension of the relationships evident in Table 8.3.2.2-3.

This information need will be satisfied through two products that will be used to demonstrate that the performance goals of function 3 have been met. The products are the results of the design activities performed under this information need. The relationships of the two products to the three processes of function 3 are shown in Table 8.3.2.2-10.

These products will be delivered to Design Issue 4.4, technical feasibility (Section 8.3.2.5) and Performance Issue 1.1, total system performance (Section 8.3.5.13). In the logic subsection for this information need, the products are used to group the approach and methods that will be used to show that the goals of this issue are met. The products are the results of the design activities and milestones identified later in the section.

Table 8.3.2.2-10. Relationship of Information Need 1.11.5 products to the processes associated with function 3 (refer to Table 8.3.2.2-3)

Product	Process
1.11.5-1 Excavation methods criteria	Limit magnitude and extent of blast-induced permeability change by blast control

Table 8.3.2.2-10. Relationship of Information Need 1.11.5 products to the processes associated with function 3 (refer to Table 8.3.2.2-3) (continued)

Product		Process
1.11.5-2	Long-term subsidence control strategy	Limit potential for subsidence by limiting extraction ratio and drift size. Backfill drifts at decommissioning

Technical basis for addressing the information need

In the following section, the information needed by planned approaches for demonstrating that goals are satisfied is linked to data already available and plans for future data gathering. Specific parameters and the logic used in identifying that they are important to resolution of this information need (1.11.5) are then identified in subsequent subsections. The accuracy with which the parameters must be obtained is discussed under Information Needs 1.11.1 and 1.11.2 (Sections 8.3.2.2.1 and 8.3.2.2.2) where the site and waste package data needed to resolve this issue are consolidated.

Link to the technical data chapters and applicable support documents

The current design data base that has been used for existing design activities, and for comparison with data needs given in the following parameters subsection, is presented in the reference design data base in Section 6.1.2. A more detailed discussion of the current data in the reference design data base may be found in the data Chapters 1 through 5; current waste package data are found in Chapter 7.

Data needed to resolve this issue that are already completed are presented in Section 6.4.2. Section 6.4.2 provides the status of resolution of Issue 1.11 and also forms some of the bases for the approaches discussed under the following logic subsection.

Finally, Information Need 1.11.1, Section 8.3.2.2.1, lists in detail the site data needs established in this information need, as well as for all other information needs under Issue 1.11. Information Need 1.11.1 also defines how well they need to be known to resolve the issue and identifies the site characterization issues under which the test plans for obtaining each site data need will be discussed.

Parameters

Parameters are those data and other information items, listed in Table 8.3.2.2-11, that are required to complete the activities and analyses necessary to develop the products that were identified in Table 8.3.2.2-10. Those activities and analyses will be performed so as to establish that the goals defined in Table 8.3.2.2-3 are met with the required level of confidence. The logic for identification of products as being necessary to satisfy the information need, as well as the basis for identification of specific parameters and information items, is provided by the following section.

Table 8.3.2.2-11. Parameters and information required to satisfy Information Need 1.11.5

Product	Parameters and input items
1.11.5-1 Excavation methods criteria	Proposed design of boreholes and drifts (Issue 4.4, Section 8.3.2.5)
	Description of proposed excavation methods (Issue 4.4)
	Estimates of the range of parameters defining damage due to excavation (Section 8.3.1.4)
1.11.5-2 Long-term subsidence control strategy	Repository layout (Information Need 1.11.3, Section 8.3.2.2.3)
	Drift and pillar stability analyses (Information Need 1.11.6, Section 8.3.2.2.6)
	Preliminary description of backfill (Issue 4.4)
	Extent of disturbed zone (Issue 1.6, Section 8.3.5.12)

Logic

The main purpose of this information need is to ensure that appropriate criteria are provided as guidelines for repository design. These criteria will initially be developed with regard to present design concepts and on the basis of constraints developed under Issue 1.10, waste package characteristics (postclosure) (Section 8.3.4.2), and Issue 1.6, ground-water travel time (Section 8.3.5.12). The need to perform a total system performance

assessment of a proposed design that conforms to these criteria is passed to Issue 1.1, total system performance (Section 8.3.5.13).

To satisfy the information need, two products that are driven by postclosure performance requirements will be developed. The first product will have limited and boundable postclosure affects. The second product will identify any measures that need to be taken to limit the potential for surface subsidence during the postclosure period. Other design criteria are established under Information Needs 1.11.3 and 1.11.4 (Sections 8.3.2.2.3 and 8.3.2.2.4).

Product 1.11.5-1: Excavation methods criteria. The process of creation of an underground excavation, whether a drift or borehole, involves the use of energy to fracture and comminute the rock mass to be removed. Some of this energy results in mechanical damage to the surrounding rock mass. This damage takes the form of opening of preexisting fractures, creation of new fractures, and movements, rotation, and loosening of structurally defined blocks of rock around the excavation. This damage can result in modification of the hydrologic environment of the host rock in the vicinity of the waste package or in the general underground facility area.

The current design basis for selection of excavation methods has been developed from the position that the potential for any modification of the properties of the host rock mass should be limited, as far as is reasonable, with currently available technology (Issue 4.4, technical feasibility (Section 8.3.2.5). On that basis, the current design of the repository incorporates construction of drifts using drill and blast methods (continuous mining is being considered, but has not yet been proved practical for welded tuff) and construction of emplacement holes using drilling methods.

Realistic criteria for establishing the suitability of these proposed construction methods must be developed based on performance assessment requirements. The current design, which is documented in the SCP-CDR (SNL, 1987), incorporates excavation techniques considering retrievability and worker health and safety concerns and meets the criteria for technological availability. Data requirements for incorporating such requirements are discussed under Issue 4.4. To perform the studies necessary to establish design criteria, it may be necessary to assume a range of characteristics of the damaged zone (not to be confused with the disturbed zone defined by the NRC): the extent and nature of new fracturing; the changes in permeability; and the shielding characteristics of the damaged zone.

Product 1.11.5-2: Long-term subsidence control strategy. Worker health and safety requirements, discussed under Issue 4.2, nonradiological health and safety (Section 8.3.2.4), and retrievability requirements, discussed under Issue 2.4, waste retrievability (Section 8.3.5.2), dictate that the excavation of the repository be usable throughout the operational period. These requirements preclude the possibility of subsidence before closure beyond that associated with predominantly elastic compression of the pillars between excavations. The responsibility under this information need is to ensure that ground movements in the vicinity of the excavations of the repository will not result in significant postclosure surface subsidence or the creation of preferred pathways for water migration.

Development of the long-term subsidence control strategy will be based on the results of drift and pillar stability analyses that are discussed under Information Need 1.11.6 (Section 8.3.2.2.6). Simple analyses will be used to estimate the possible extent and magnitude of loosening of the rock mass above a backfilled drift. Such analyses are expected to demonstrate with a high level of confidence that the potential for surface subsidence can be limited if current repository design concepts are implemented. Whether rock movements after closure may impact the system performance will be judged relative to the extent of the disturbed zone. If appropriate, the need for total system performance assessment analyses incorporating nonconservative estimates of permeability changes after closure will be defined.

8.3.2.2.5.1 Design Activity 1.11.5.1: Excavation methods criteria

The objective of this design activity is to identify any constraints to be placed on excavation methods because of postclosure performance considerations. The technical basis part of the previous section discusses the role of this activity in Information Need 1.11.5, and Section 8.3.2.2.1 discusses the requirements for excavation relative to induced permeability and porosity changes. Table 8.3.2.2-11 presents the excavation parameters and input required to satisfy this information need for this activity.

8.3.2.2.5.2 Design Activity 1.11.5.2: Long-term subsidence control strategy

The objectives of this design activity are to (1) develop a position regarding the potential for postclosure surface subsidence and the impact of postclosure ground movement on containment and isolation and (2) determine if current goals are adequate to limit potential for subsidence. The technical basis part of Section 8.3.2.2.5 discusses the role of this activity in Information Need 1.11.5, and Section 8.3.2.2.1 discuss the data requirements for this activity. Table 8.3.2.2-11 gives the long-term subsidence parameters and input required to satisfy this information need.

8.3.2.2.5.3 Application of results

The products and information developed under this information need will be used as input to the reference postclosure design (Information Need 1.12.7, Section 8.3.3.3.7) and as criteria for the design of the preclosure repository developed under Issues 4.2, nonradiological health and safety (Section 8.3.2.4), and 4.4, technical feasibility (Section 8.3.2.5).

The site parameters identified under this information need are conveyed to the site characterization programs by Information Need 1.11.1 (Section 8.3.2.2.1), along with details about how well the site data should be determined.

8.3.2.2.6 Information Need 1.11.6: Repository thermal loading and predicted thermal and thermomechanical response of the host rock

The discussion under this information need extends the discussion of function 4, which was presented in the issue resolution strategy section for this issue (1.11). The approaches or methods to be used to calculate or otherwise establish that the anticipated or actual performance will meet the performance goals stated in Table 8.3.2.2-4. In many instances, the approaches, which follow in the logic subsection for this information need, require site data, performance information, or design information to make such an evaluation. The site data needs of this information need (1.11.6) are identified in the following parameters section. These needs are passed to the site characterization programs. Performance and design information needs are also identified in the following parameters section. In many instances, these performance and design information needs are the results or conclusions of work that depends on site data. The call for such site data is in the issue where the work is done and is not repeated here.

Table 8.3.2.2-4 identifies six processes necessary for meeting function 4. Each of these processes was related to one or more performance measures and their associated performance goals and desired confidences. The approaches and data needs discussed here are an extension of the relationships evident in that table.

This information need will be satisfied through five products that will be used to demonstrate that the performance goals of function 4 have been met. The products are the results of the design activities performed under this information need. The relationship of the five products to the six processes of function 4 is shown in Table 8.3.2.2-12.

These products may be delivered to other information needs under this issue or under other design or performance issues. In the following logic subsection, the products are used to group the approach and methods that will be used to show that the goals of this issue are met. Products are the results of the design activities and milestones identified later in the section.

Technical basis for addressing the information need

In the following subsection, the information needed by planned approaches for demonstrating that goals are satisfied is linked to data already available and plans for future data gathering. Specific parameters and the logic used in identifying their importance to resolution of this information need (1.11.6) are then identified in subsequent subsections. The accuracy with which the parameters must be obtained is discussed under Information Needs 1.11.1 and 1.11.2 (Sections 8.3.2.2.1 and 8.3.2.2.2) where the site and waste package data needed to resolve this issue are consolidated.

Table 8.3.2.2-12. Relationship of Information Need 1.11.6 products to the processes associated with function 4 (Table 8.3.2.2-4). (Asterisks indicate direct relationship between products and processes.)

Process	Product				
	Allowable APD[a]	Borehole spacing strategy	Sensitivity studies	Strategy for containment enhancement	Reference calculations[b]
Limit temperature changes in selected barriers	*		*		*
Limit deleterious rock movement or preferred pathways	*		*		*
Limit impact on surface environment	*				
Vary borehole and drift spacing to control thermal loading and container temperature	*	*	*	*	*
Limit potential for borehole collapse	*	*	*		*
Limit corrosiveness of container environment		*		*	

[a]APD = areal power density.

[b]Thermomechanical calculations in the reference information base for general Project reference and use.

Link to the technical data chapters and applicable support documents

The current design data base that has been used for existing design activities, and for comparison with data needs given in the following parameters subsection, is presented in the reference design data base in Section 6.1.2. A more detailed discussion of the current data in the reference design data base may be found in the data chapters (1 through 5), and current waste package data are found in Chapter 7.

Data that are needed to resolve this issue and that are already completed are presented in Section 6.4.2. This section provides the status of resolution of this issue (1.11), and also forms some of the bases for the approaches discussed under the following logic subsection.

Finally, Information Need 1.11.1 (Section 8.3.2.2.1) lists in detail the site data needs established in this information need, as well as those for all other information needs under this issue. That information need also defines how well the data must be known to resolve the issue and identifies the site characterization issues under which the test plans for obtaining each site data need will be discussed.

Parameters

Parameters defined in this section are treated at two levels. At the first level (Table 8.3.2.2-13) the analyses and input items required to address this information need are identified. Specific parameters required to complete the analyses are identified at the second level (Table 8.3.2.2-14). This method of presentation has been adopted because there is considerable overlap between the types of analyses that will be performed to develop the five products identified under this information need. The iterative nature of the design process is also evident; for example, the borehole spacing documents require the use of container scale thermal analyses and those analyses require initial estimates of the borehole spacing. The analyses will be used to ensure that goals identified in Table 8.3.2.2-4 are met with an appropriate level of confidence. The logic for the identification of the products and the analyses required to prepare them are provided by the following subsection. Site parameters required to complete the analyses are determined by the input needs of the computer models and other analytical tools to be used.

Logic

The burden of ensuring that the repository facilities will meet all applicable performance objectives lies with this information need. Other information needs under this issue are primarily concerned with establishing the design bases (such as available space) and constraints that must be placed upon the design as a consequence of postclosure performance concerns. This information need is also concerned with the development of reference calculations that provide a consistent set of predictions of the behavior of the repository for performance assessment.

Table 8.3.2.2-13. Analyses and input items required to resolve Information Need 1.11.6

Product		Parameters and input items
1.11.6-1	Areal power density (APD)	Drift stability criteria (Issues 2.4 and 4.4, Sections 8.3.5.2 and 8.3.2.5) Constraints established by sealing program (Issue 1.12, Section 8.3.3.2) Far-field performance criteria, including limits on temperature change and permeability changes on adjacent strata Surface temperature change, and surface uplift limits Near-field limits on host rock temperature, as it influences container environment (Issue 1.10, Section 8.3.4.2) Far-field thermal and thermomechanical analyses (Table 8.3.2.2-14) Near-field thermal and thermomechanical analyses (Table 8.3.2.2-14)
1.11.6-2	Borehole spacing	Borehole stability criteria (Issues 2.4 and 4.4) APD Container and container environment constraints (Issue 1.10) Container scale thermal and thermomechanical analyses (Table 8.3.2.2-14)
1.11.6-3	Sensitivity studies	Container scale thermal and thermomechanical analyses (Table 8.3.2.2-14) Drift scale thermal and thermomechanical analyses (Table 8.3.2.2-14) Far-field thermal and thermomechanical analyses (Table 8.3.2.2-14) Ranges of feasible parameters defined in Table 8.3.2.2-14 Off-normal conditions scenario
1.11.6-4	Strategy for containment enhancement	Proposed water usage (Issue 4.4) APD and borehole spacing Waste package characteristics (postclosure) (Issue 1.10)
1.11.6-5	Reference calculation	Repository design Container thermal and thermomechanical scale analyses Drift thermal and thermomechanical analyses Far-field thermal and thermomechanical analyses

Table 8.3.2.2-14. Parameters for thermal and thermomechanical analyses

Product	Parameters and input items
Container scale analyses	Borehole dimensions and spacing Waste package description Container dimensions Container thermal output Container thermal decay characteristics Liner and overpack specification Geologic description of site Stratigraphy Jointing orientation, frequency, distribution Rock mass thermal and thermomechanical properties TSw2 and adjacent units Saturation Thermal conductivity Heat capacity Thermal expansion coefficient Rock mass deformation modulus Rock mass strength In situ stress Rock matrix elastic modulus Rock matrix Poisson's ratio Rock matrix strength Joint orientation Joint spacing Joint strength Joint normal stiffness Joint shear stiffness
Drift scale analyses	Areal power density Waste decay characteristics (See listing under container scale analyses) Drift dimensions and spacing Waste emplacement configuration Geologic description of site Stratigraphy Rock mass thermal and thermomechanical properties of TSw2 and adjacent units (see listing under container scale analyses) Rock support measures

Table 8.3.2.2-14. Parameters for thermal and thermomechanical analyses (continued)

Product	Parameters and input items
Far-field analyses	Areal power density Waste decay characteristics (see listing under container scale analyses) Repository layout Geologic description of site Stratigraphy Topography Fault locations and properties Jointing orientation, frequency, distribution Rock mass thermal and thermomechanical properties of all units, including overburden (see listing under container scale analyses)

Five products have been identified as needed to satisfy this information need: (1) the areal power density, (2) the emplacement borehole spacing, (3) sensitivity studies, (4) strategy for containment enhancement, and (5) reference calculations. Developing these products involves consideration of multiple processes (Table 8.3.2.2-12) and the application of the appropriate analyses (identified in Table 8.3.2.2-13). The following discussion treats first the products and then the analyses upon which they rely.

Product 1.11.6-1: Areal power density. The areal power density (APD) is the single most important characteristic of the repository since it can be directly related to the capacity of the site, the repository layout, and the extent to which the original characteristics of the site are modified as a consequence of waste emplacement. The method of development of the APD involves performing thermal and thermomechanical analyses. The results of those analyses are compared with constraints or goals established under other design issues and the performance issues. Given waste with a particular set of characteristics, the average thermal loading is varied until the larger scale performance criteria are met. Analyses of drifts, and possibly of boreholes, are then performed to ensure that near-field criteria are also satisfied for the selected APD and the given thermal power decay characteristics of the waste form.

Product 1.11.6-2: Borehole spacing. The borehole spacing is very closely related to the areal power density (APD), and when the APD is being determined it may be necessary to perform drift or borehole scale calculations that assume a particular spacing. Borehole spacing is an important design factor because (1) there may be several different arrangements of waste (different borehole spacings), each with the same APD, that meet constraints; and (2) the considerable variability of the thermal output of the waste will require that the borehole spacing be a variable. This product

must develop the strategy for selecting borehole spacing based on an approach that considers thermomechanical interaction between boreholes and between drifts and boreholes, and equipment constraints on borehole construction or waste emplacement. These analyses will provide detailed assessment of the temperatures near the emplacement boreholes. These assessments will be compared to criteria established under Issues 1.10, waste package characteristics (postclosure) (Section 8.3.4.2); 2.4, waste retrievability (Section 8.3.5.2); and 4.4, technical feasibility (Section 8.3.2.5).

Product 1.11.6-3: Sensitivity studies. Sensitivity studies will be performed to evaluate the effects of uncertainty in the description of the waste form and the geologic setting. At present it is assumed that such studies will rely on repeated analyses incorporating realistic parameter variations. The results of these analyses may be expressed quantitatively as sensitivity coefficients and incorporated within a finalized methodology of uncertainty analysis.

Product 1.11.6-4: Strategy for containment enhancement. Under the discussion of the borehole spacing product, it was noted that more than one spacing may meet all constraints; however, these different ways to distribute the waste may not all perform equally. This product will document what has been done to make sure that the significant alternatives or ways of enhancing performance have not been overlooked. For example, one goal is to keep the container dry by maintaining temperatures above boiling for 300 yr; however, at the edges of the underground facility, temperatures will not be as high as at the middle. This product will investigate increasing the waste loading at the edges of the underground facility to maintain higher temperatures there. This product will rely primarily on container scale thermal calculations and is intended to respond to the requirements of Issue 1.10, waste package characteristics (postclosure) (Section 8.3.4.2).

Product 1.11.6-5: Reference calculations. The repository design as shown in Chapter 6 was developed in support of the site characterization plan. The design is expected to be refined as the site investigation proceeds, and after field evaluation at the exploratory shaft. These refinements will be documented as part of the advanced conceptual design and license application design activities. At every stage it is important to have a complete set of referenceable predictions of the behavior of the repository system. Such predictions provide a basis on which to assess the suitability of the proposed design and are important considerations when developing the needs for supporting laboratory and field investigations. These predictions (or reference calculations) will be based on progressively better designs and site data of improving quality.

Analysis of thermal and thermomechanical response. Before discussing the specifics of analyses it is important to emphasize an assumption upon which the subsequent discussion relies. The assumption is that responsibility for ensuring that the retrieval option is maintained until the time of closure rests with Issues 4.4, technical feasibility (Section 8.3.2.5), and 2.4, waste retrievability (Section 8.3.5.2). Accordingly, it is assumed that necessary steps will be taken to validate the approach used to ensure that reasonable maintenance requirements and retrieval will be met under those issues. Achieving that assurance will necessarily require that the damaged zone around the boreholes and drifts, as it exists at the time of closure,

will be reasonably characterized. For the postclosure period it remains to be demonstrated that the container integrity will not be violated and that the disturbed zone is not extended as a consequence of the changing thermal stress field.

The terms near-field and far-field are often used when discussing analyses on different scales. Here it is more convenient to subdivide the near-field into the container scale and the drift scale, on the basis that analyses on those two scales may be conducted independently. (That is likely to be true for horizontal emplacement, but it may be more difficult to separate the two for the vertical emplacement option.) The following paragraphs discuss the scope of the analyses anticipated to be performed on these three scales and the types of models to be used. Further, the need for supporting activities and field studies to validate these models is addressed.

Validation of the computer models to be used to verify the design of the waste emplacement configuration is discussed under Issue 4.4, technical feasibility (Section 8.3.2.5). No additional validation of the finite-element models discussed there is considered necessary, because there will be no significant change in the conditions that they seek to analyze. As such, this issue does not call for site data to validate the models.

Container scale analyses. In Table 8.3.2.2-5 performance goals are defined for the waste container and the adjacent rock. Thermal and thermo-mechanical modeling will be used to ensure that these goals continue to be met beyond closure of the underground facility. The design parameters that may be selected to ensure that the goals are met are the waste package spacing and the areal power density. In general, the analyses will be identical to those performed for the preclosure period. Namely, either two- or three-dimensional analyses will be performed using finite-element models that incorporate a description of jointed rock behavior. Selection of a three-dimensional idealization, as opposed to two-dimensional, will be based on the geometry of the waste emplacement configuration. However, two-dimensional analyses are expected to be adequate for evaluation of horizontal emplacement boreholes, while three-dimensional analyses may be required for vertical boreholes. (For vertical emplacement, the waste packages may be too close to the emplacement drift to allow the assumption of symmetry necessary to use two-dimensional analysis techniques.)

Because the emplacement borehole liner is expected to have a limited life, the analyses should not include the possible beneficial effect of rock support during the early postclosure period. In the absence of any such support it is possible that blocks of rock will become detached from the borehole wall and come in contact with the waste container. Prediction of the size of those blocks and the loads that could be imposed on the container are considered important in view of load constraints defined under Issue 1.10, waste package characteristics (postclosure) (Section 8.3.4.2). The finite-element models currently under development within the Yucca Mountain Project do not address block failure. Hence, it will be necessary to apply other techniques to evaluate the loading, such as wedge analysis, key block analysis, and use of models based on application of the distinct element method. These other methods should incorporate realistic descriptions of the geometry of the rock surrounding the emplacement borehole and include the effects of thermal loading. The thermal load history (boundary condition)

used in the wedge or key block analysis may be obtained from thermomechanical analyses performed to evaluate goals for the waste container and adjacent rock.

Drift scale analyses. The objective of drift-scale analyses of the postclosure period is to ensure that no new paths to the accessible environment, or extension of the disturbed zone, will occur. The potential for such effects can be mitigated by backfilling the emplacement drifts before closure. Good drift maintenance performed during the preclosure period, the amount of void space around the drift, the compaction characteristics of the backfill, and the bulking factor of the host rock will limit the amount of rockfall in the case of localized rock failure. The possible implications of such disturbance can be evaluated using performance assessment models based on assumptions about the distribution of void space around the drift. It is also recommended that such evaluations be supported by thermal and thermomechanical analyses intended to evaluate the behavior under the applied thermal loading.

Data for the postclosure drift analyses will include a description of the drift at the time of closure, with particular emphasis placed on definition of the extent of damage and a description of the backfill. The finite-element models described under Issue 4.4, technical feasibility (Section 8.3.2.5), will be used to perform analyses. The only additional component of the models will be the backfill. Because primary reliance will be placed on performance assessment to evaluate the acceptability of the system, detailed validation of thermomechanical models of the backfilled drifts is not considered necessary.

Far-field analyses. Far-field thermal and thermomechanical analyses of the postclosure repository configuration will be performed to confirm that the far-field performance goals continue to be met. The tools for these analyses will be the same as those used for container and drift-scale analyses, namely, finite-element, thermomechanical analyses of representative cross sections of the repository. There are no new physical processes to be analyzed and there are no additional bases for evaluating the potential for deleterious rock movements or creation of preferred pathways other than the potential effects of faulting. Faulting should be included in the far-field thermomechanical models to assess their potential effects. The far-field analyses of the repository system require the same data and techniques as other thermomechanical analyses. Temperature-induced displacements in the rock mass will be examined and will consider the possibility of movement along preexisting features such as faults. If movement on features that intersect the repository facility is possible, the analyses described in Section 8.3.2.5 will be extended to examine possible effects. Seismically induced movements will be considered in conjunction with temperature-induced effects.

8.3.2.2.6.1 Design Activity 1.11.6.1: Thermal loading for underground facility

The objective of this design activity is to establish the allowable thermal loading as a function of waste age and burnup. Determination will

start with far-field calculations and consider near-field effects to ensure practical waste distribution exists that meets near-field constraints. The technical basis part of the previous section discusses the approach to determining the allowable APD, and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.6.2 Design Activity 1.11.6.2: Borehole spacing strategy

The objective of this design activity is to establish strategy for choosing borehole spacings as a function of waste thermal output as affected by waste type, age, and burnup. Strategy will be designed to ensure that spacings chosen will satisfy all near-field constraints. The technical basis part of Section 8.3.2.2.6 discusses the approach to establishing a borehole spacing strategy, and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.6.3 Design Activity 1.11.6.3: Sensitivity studies

The objective of this design activity is to determine predicted repository thermal and thermomechanical response to variations in model input data. This information will be used to evaluate adequacy of data gathered and to determine goals have been met with proper confidence. The technical basis part of Section 8.3.2.2.6 discusses this approach to sensitivity studies, and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.6.4 Design Activity 1.11.6.4: Strategy for containment enhancement

The objective of this design activity is to document how design of underground facility has taken into account containment, in particular, the goal for Issue 1.10 (Section 8.3.4.2) of keeping the containers dry for 300 yr. The technical basis part of Section 8.3.2.2.6 discusses the approach to this strategy, and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.6.5 Design Activity 1.11.6.5: Reference calculations

The objective of this design activity is to provide a consistent set of calculations with proper quality assurance of thermal and thermomechanical response of host rock that can be used by performance assessment issues. The technical basis part of Section 8.3.2.2.6 discusses the approach to these calculations, and Section 8.3.2.2.1 discusses the data requirements for this activity.

8.3.2.2.6.6 Application of results

This information will be input for the advanced conceptual design and licensing application design reports, documented in the reference postclosure design (Information Need 1.11.7 (Section 8.3.2.2.7)) and used as criteria for the repository design developed by Issue 4.4, technical feasibility (Section 8.3.2.5). It will be used in Issues 1.1, total system performance (Section 8.3.5.13), and 1.10, waste package characteristics (postclosure) (Section 8.3.4.2), as part of performance assessment.

The site parameters identified under this information need are conveyed to the site characterization programs by Information Need 1.11.1, site characteristics needed for design (Section 8.3.2.2.1), along with details about how well the site data should be determined.

8.3.2.2.7 Information Need 1.11.7: Reference postclosure repository design

This information need does not correspond to an issue resolution function identified in the issue resolution strategy (Section 8.3.2.2) for this issue (1.11). Nor does it require the acquisition of site data. Rather, this information need will be satisfied using data acquired under other information needs, as well as results of analyses conducted under other information needs.

This information need will be satisfied by two products:

1. Reference postclosure design provides the reference postclosure design of the repository, which will form part of the basis for the postclosure performance assessment of the repository (to satisfy part 2 of this issue).

2. Documentation of compliance will demonstrate compliance of the postclosure design with the requirements of 10 CFR 60.133 (satisfying part 1 of this issue). This product will be documented in the advanced conceptual design and license application design reports.

Technical basis for addressing the information need

In the subsequent subsections a link is provided to other sections of the SCP and supporting documents, including reference to documentation of the current status of satisfying this information need as found in Section 6.4. The reference postclosure design will be documented in the reference information base. An explanation of the logic of what is required to satisfy this information need is also given.

Link to the technical data chapters and applicable support documents

The current design concepts and drawings are documented in Section 6.2 and in Chapters 3 and 4 of the SCP-CDR (SNL,1987). The reference design drawings that result from this information need will be part of the basis for postclosure performance assessment of the repository by the following issues:

Issue	Short title	SCP section
1.1	Total system performance	8.3.5.13
1.3	Ground-water protection	8.3.5.15
1.4	Containment by waste package	8.3.5.9
1.5	Engineered barrier system release rates	8.3.5.10
1.6	Ground-water travel time	8.3.5.12
1.8	NRC siting criteria	8.3.5.17
1.9	Higher level findings--postclosure	8.3.5.18

Parameters

The following information needs or investigations will furnish information necessary to develop the postclosure design of the underground facility:

Information need or investigation	Subject
1.11.3	Underground facility orientation and layout (Section 8.3.2.2.3)
1.11.4	Design constraints to limit water usage (Section 8.3.2.2.4)
1.11.6	Thermomechanical effects on postclosure design (Section 8.3.2.2.6)
1.12.2	Seal materials (Section 8.3.3.2.2)
1.12.3	Emplacement methods for seals (Section 8.3.3.2.3)
1.12.4	Reference seal designs (Section 8.3.3.2.4)
4.4.7	Design analyses for technical feasibility (Section 8.3.2.5.7)
8.3.1.4.1	Integrated drilling program (stratigraphy, structure, rock properties)
8.3.1.9.1	Degradation of surface markers and monuments

Logic

This information need will evaluate criteria for reference design and construction drawings and transmit these criteria to Issue 4.4, technical feasibility (Section 8.3.2.5). Specific drawings that result will be supplied, as they are available, to the reference information base during the advanced conceptual design and license application design phases.

The information that must be documented as part of the reference postclosure underground facility design is as follows:

1. The location of underground openings including their preclosure size and shape and their drainage pattern.

2. The anticipated postclosure state of the openings including backfill and reasonable degradation. The boreholes on the average are expected to be stable and meet containment requirements; however, drifts that will remain stable for some period after repository closure will not be relied on to be open and may be backfilled.

3. The documentation of location, function, and design of the seals for shafts, drifts, and exploratory drill holes. This documentation will be produced by Issue 1.12, seal characteristics (Section 8.3.3.2). Documentation of this information will be included in the reference postclosure design.

4. The criteria for dismantling of the underground structures and facilities including statement of materials that will be left in place (plan for decommissioning will be in Issue 4.4, technical feasibility, Section 8.3.2.5).

5. Documentation of surface monuments, if any (Issue 1.12).

8.3.2.2.7.1 Design Activity 1.11.7.1: Reference postclosure repository design

The objective of this design activity is to establish what information will constitute the reference postclosure design for use in performance assessment and document this information in the advanced conceptual design and license application design reports. The previous section discusses the role of the activity in resolving Issue 1.11.

8.3.2.2.7.2 Design Activity 1.11.7.2: Documentation of compliance

The objective of this design activity is to document that the issue has been resolved by determining if the postclosure design complies with the design goals of this issue and to document this compliance in the advanced conceptual design and license application design reports.

8.3.2.2.7.3 Application of results

The reference design produced to satisfy this information need will be placed in the reference information base for use as input to the following performance assessment issues:

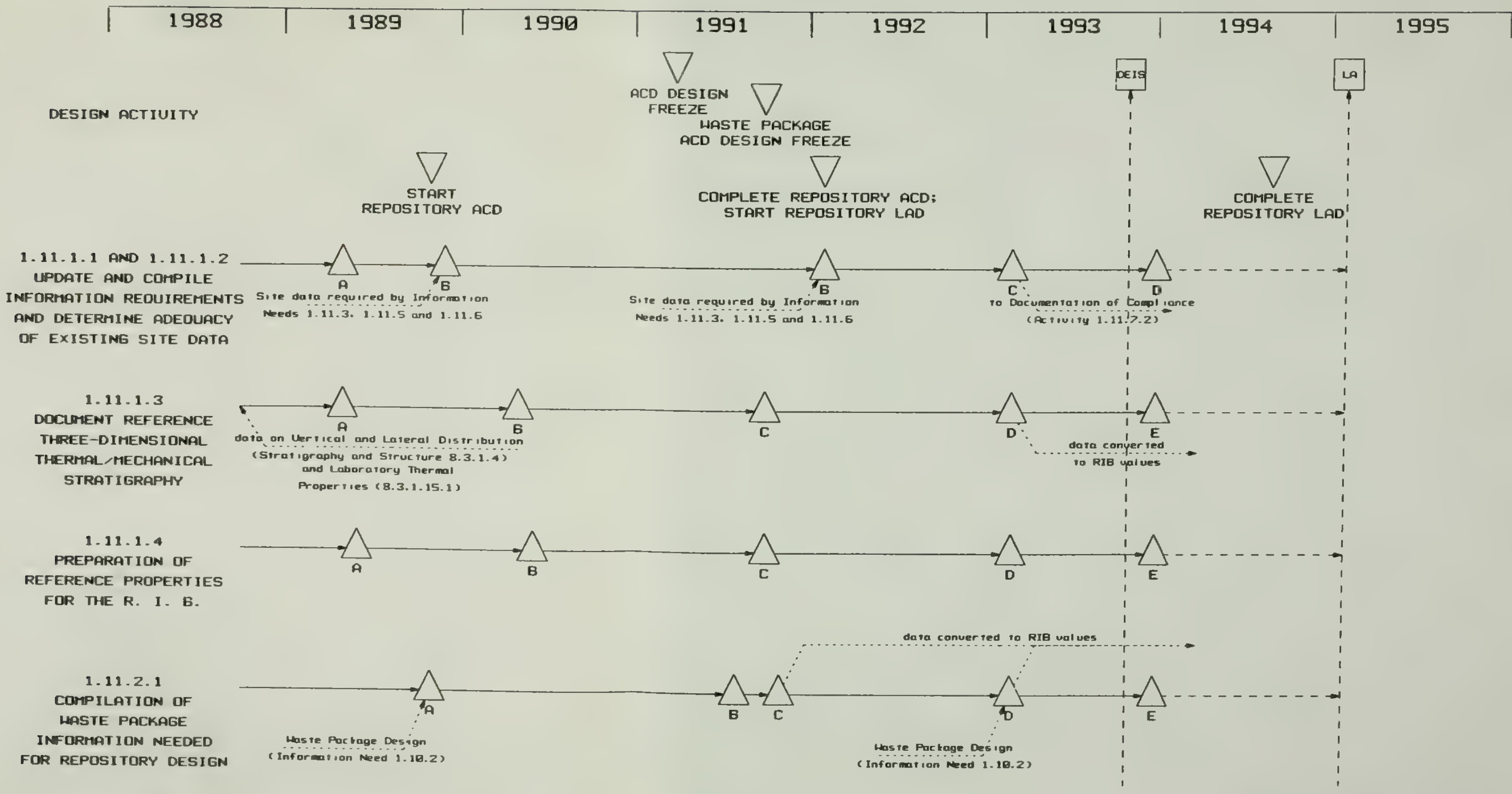
Issue	Short title	SCP section
1.1	Total performance assessment	8.3.5.13
1.3	Ground-water protection	8.3.5.15
1.4	Containment by waste package	8.3.5.9
1.5	Engineered barrier system release rates	8.3.5.10
1.6	Ground-water travel time	8.3.5.12
1.7	Performance confirmation	8.3.5.16
1.8	NRC siting criteria	8.3.5.17
1.9	Higher level findings--postclosure	8.3.5.18

8.3.2.2.8 Schedule for configuration of underground facilities

Issue 1.11 (configuration of underground facilities) includes seven information needs, which contain 22 design activities. The schedule information for these design activities is summarized in Figure 8.3.2.2-3. This figure includes the design activity number and a brief description, as well as major events associated with each activity. A major event, purposes of these schedules, may represent the initiation or completion of an activity, completion or submittal of a report to the DOE, an important data feed, or a decision point. Solid lines on the schedule represent activity durations and dashed lines show interfaces among activities as well as transferred into or out of this design issue. The events shown on the schedule and their planned dates of completion are provided in Table 8.3.2.2-15.

The activity-level schedules, in combination with information provided in the logic diagram for this issue (Figure 8.3.2.2-1), are intended to provide the reader with a basic understanding of the relationships between major elements of the site, performance and design programs. The information provided in Table 8.3.2.2-15 and Figure 8.3.2.2-3, however, should be viewed as a snapshot in time.

The overall program schedule presented here is consistent with the Draft Mission Plan Amendment (DOE, 1988a). The site characterization program will undergo a series of refinements following issuance of the statutory SCP. Refinements will consider factors both internal and external to the site characterization program, such as changes to the quality assurance program. Such refinements are to be considered in ongoing planning efforts, and changes that are implemented will be reflected in the semiannual progress reports. Summary schedule information for this and other repository design issues can be found in Sections 8.5.3 and 8.5.6.



(SEE LEGEND ON PAGE 2 OF 5)

Figure 8.3.2.2-3. Schedule information for Issue 1.11 (configuration of underground facilities). See Table 8.3.2.2-15 for description of major events. This network is consistent with the Draft Mission Plan Amendment (DOE, 1988a) schedule. Revisions will be published in semiannual site characterization progress reports as new information becomes available. (page 1 of 5)

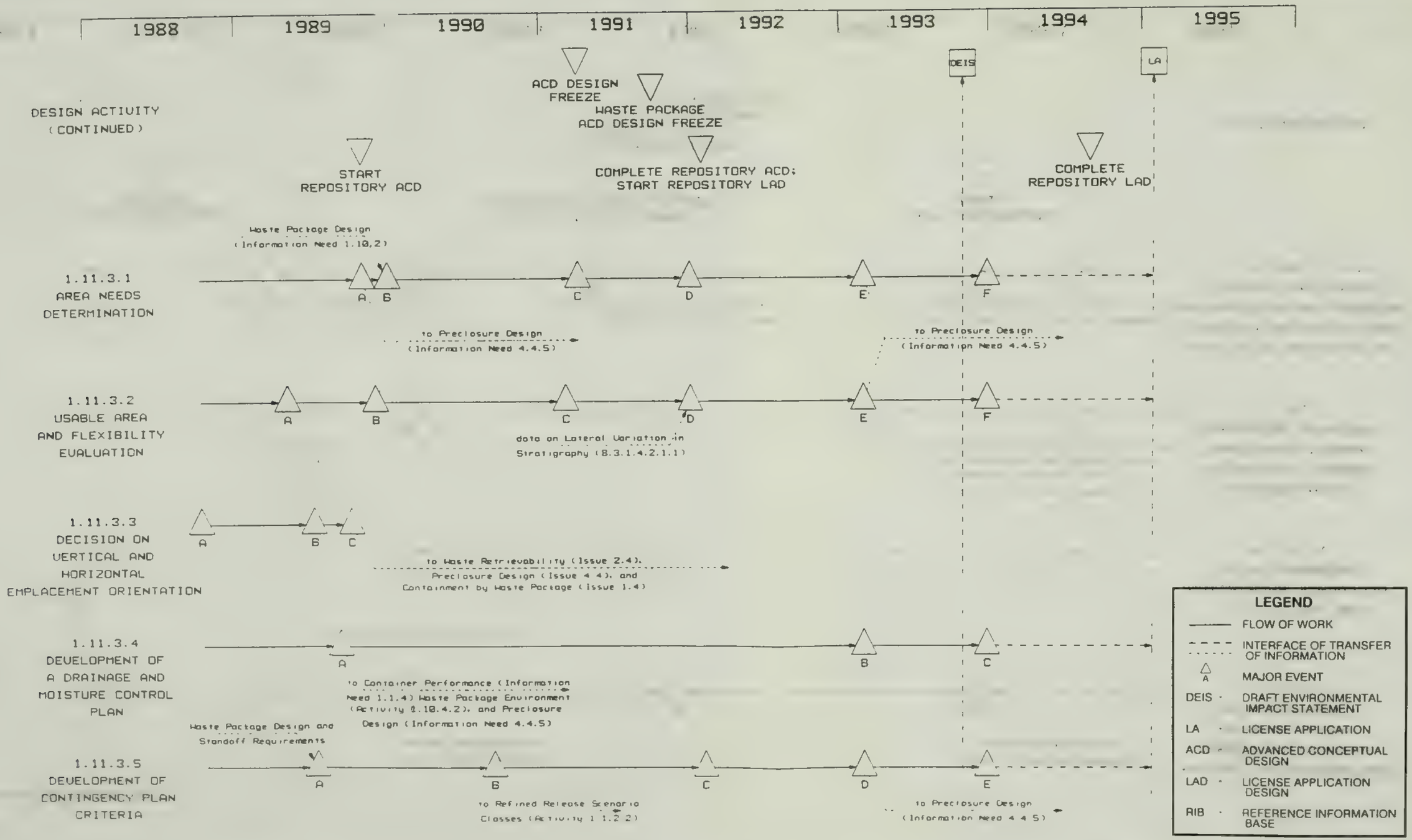


Figure 8.3.2.2-3. Schedule information for activities in Issue 1.11 (configuration of underground facilities). See Table 8.3.2.2-15 for description of major events. This network is consistent with the Draft Mission Plan Amendment (DOE 1988a) schedule. Revisions will be published in semiannual site characterization progress reports as new information becomes available. (page 2 of 5)

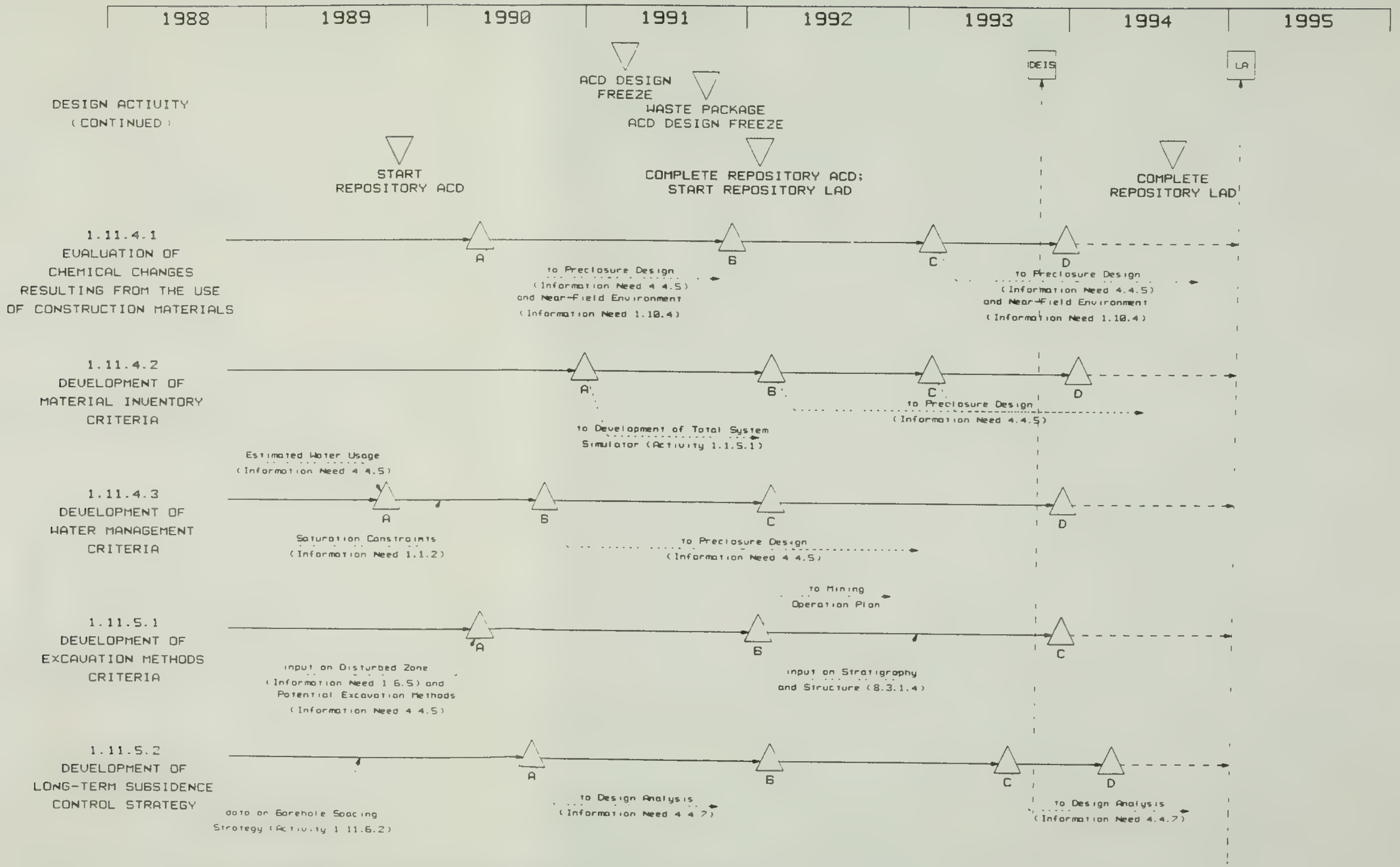


Figure 8.3.2.2-3. Schedule information for activities in Issue 1.11 (configuration of underground facilities) See Table 8.3.2.2-15 for description of major events This network is consistent with the Draft Mission Plan Amendment (DOE 1988a) schedule Revisions will be published in semiannual site characterization progress reports as new information becomes available (page 3 of 5)

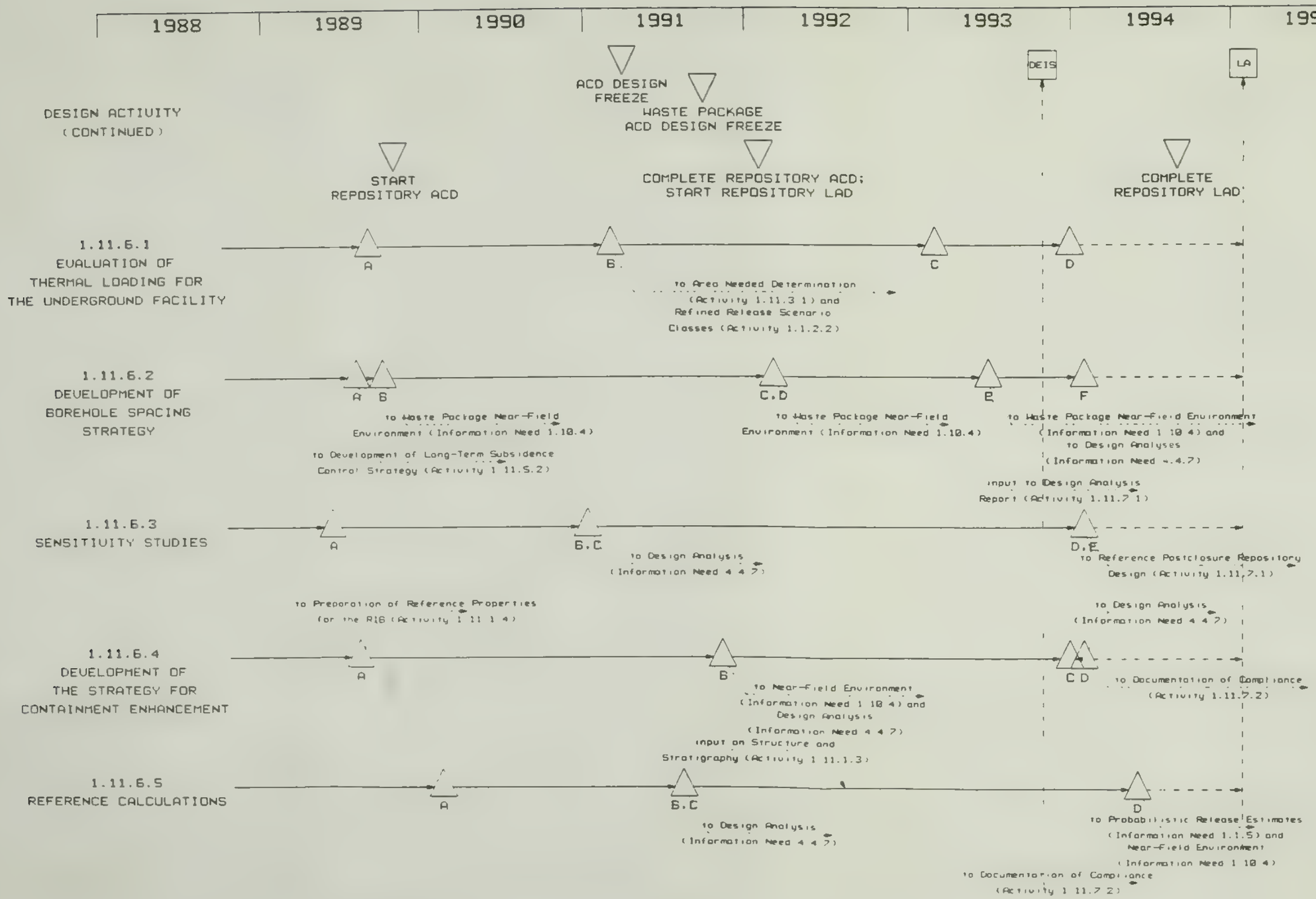


Figure 8.3.2.2-3 Schedule information for activities in Issue 1.11 (configuration of underground facilities) See Table 8.3.2.2-15 for description of major events This network is consistent with the Draft Mission Plan Amendment (DOE 1988a) schedule Revisions will be published in semiannual site characterization progress reports as new information becomes available **(page 4 of 5)**

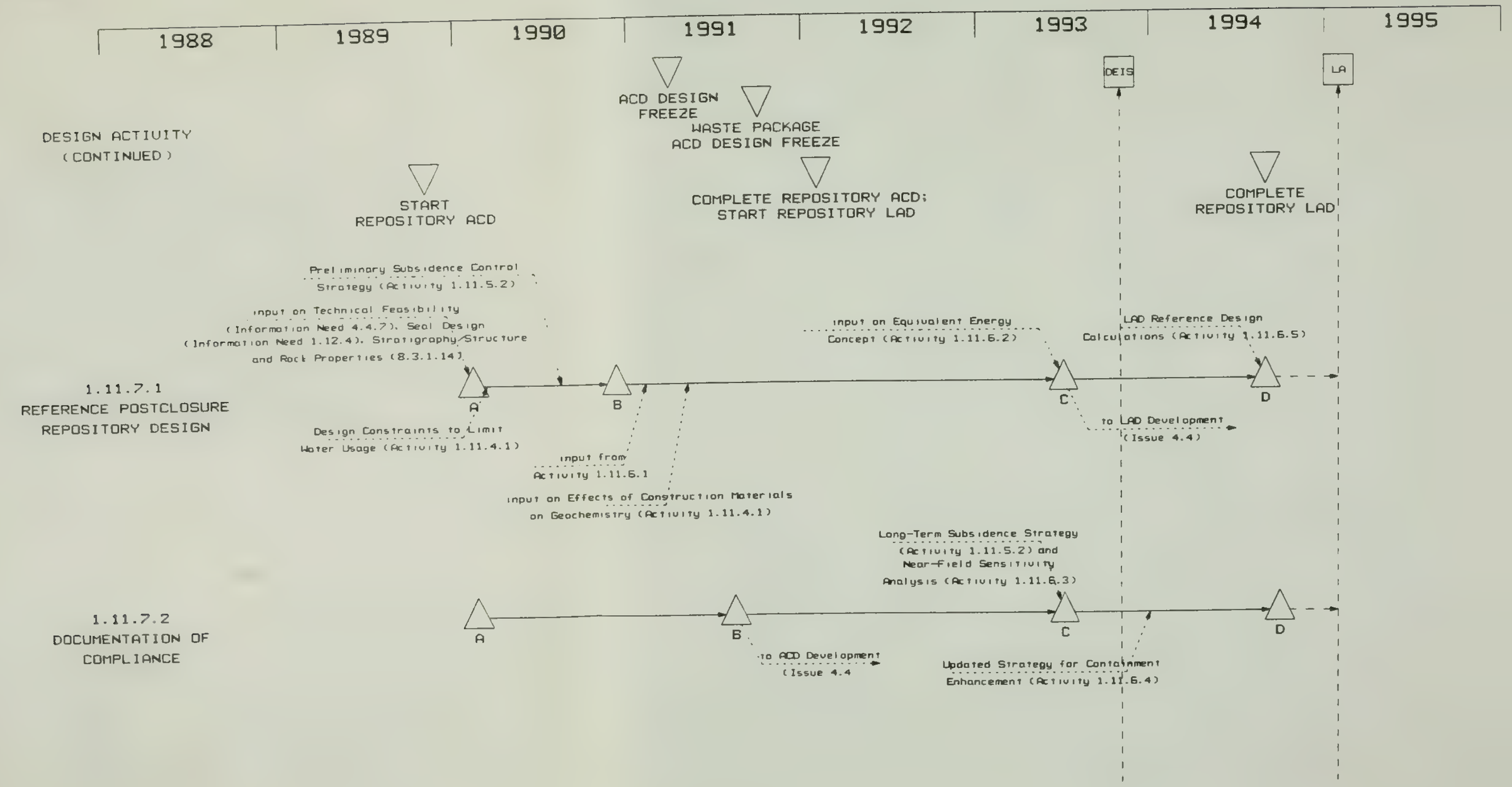


Figure 8.3.2.2-3. Schedule information for activities in Issue 1.11 (configuration of underground facilities) See Table 8.3.2.2-15 for description of major events This network is consistent with the Draft Mission Plan Amendment (DOE, 1988a) schedule Revisions will be published in semiannual site characterization progress reports as new information becomes available (page 5 of 5)

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 1 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.1.1 and 1.11.1.2	Update and compile information requirements; Determine existing site data adequacy	A	Complete preliminary results of data adequacy assessment	4/89
		B	Input of site characterization data required by underground facility design and thermal loading studies; continue adequacy assessment	11/89 1/92
		C	Results of the updated data adequacy assessment available; begin final update of data adequacy assessment	2/93
		D	Complete determination of the adequacy of existing data for postclosure repository design	12/93
1.11.1.3	Document reference 3-D thermal/mechanical stratigraphy	A	Draft report available to the U.S. Department of Energy (DOE) on the reference thermal/mechanical stratigraphy for advanced conceptual design (ACD)	4/89
		B	Updated information on the reference thermal/mechanical stratigraphy for ACD available to Design Activity 1.11.3.3 (vertical and horizontal emplacement orientation decision)	11/89

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 2 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.1.3	Document reference 3-D thermal/ mechanical stratigraphy (continued)	C	Draft report available to DOE describing the reference thermal/mechanical stratigraphy of Yucca Mountain for license application design (LAD)	9/91
		D	Updated information on the reference thermal/mechanical stratigraphy for LAD available to Design Activities 1.11.6.5 (reference calculations) and 1.11.7.2 (documentation of compliance)	2/93
		E	Draft of final report on thermal/ mechanical stratigraphy available to DOE	12/93
1.11.1.4	Preparation of reference properties for the reference information base	A	Begin conversion of thermal/mechanical stratigraphy measurements and data to reference data	5/89
		B	Begin conversion of updated information on the thermal/mechanical stratigraphy for ACD to reference data	5/90
		C	Draft report available to DOE documenting updated reference thermal/ mechanical properties for LAD	9/91

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 3 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.1.4	Preparation of reference properties for the reference information base (continued)	D	Final updated thermal/mechanical properties available for the reference information base	2/93
		E	Draft of final report on thermal/mechanical properties available to DOE	12/93
1.11.2.1	Compilation of waste package information needed for repository design	A	Initial information on waste package characteristics required for design of the underground facility available	10/89
		B	Updated information on waste package characteristics required for design of the underground facility available	9/91
		C	Complete determination and compilation of waste package information required for underground facility design	1/92
		D	Updated information on waste package characteristics available for the reference information base	5/93
		E	Final report on compilation of waste package information available to DOE	3/94

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 4 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.3.1	Area needed determination	A	Complete preliminary determination of area needed	10/89
		B	Input updated waste package characteristics for further studies of area needed	1/90
		C	Results of the determination of allowable far-field areal power density (from Design Activity 1.11.6.1) available for area needed determination	12/91
		D	Complete determination of area needed	12/91
		E	Updated determination of area needed available to Information Need 4.4.5 (reference preclosure repository design)	2/93
		F	Draft of final report on area needed determination available to DOE	12/93
1.11.3.2	Usable area and flexibility evaluation	A	Information on the reference thermal/mechanical stratigraphy for ACD (from Design Activity 1.11.1.3) available for the evaluation of usable area and flexibility	4/89

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 5 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.3.2	Usable area and flexibility evaluation (continued)	B	Complete evaluation of usable area and flexibility for ACD	11/89
		C	Input current site data (from 8.3.1.8.3.1.3, 8.3.1.2.3.1.2, 8.3.1.4, and 8.3.1.14) and reference preclosure repository design information for the evaluation of usable area and flexibility for LAD	2/91
		D	Complete evaluation of usable area and flexibility for LAD	12/91
		E	Updated evaluation of usable area and flexibilty available	2/93
		F	Draft of final report on usable area and flexibility available to DOE	12/93
1.11.3.3	Decision on vertical and horizontal emplacement orientation	A	Complete preliminary performance comparison of vertical and horizontal emplacement of the waste packages	10/88
		B	Information on reference waste package emplacement configurations (from Information Need 1.10.3) available for emplacement orientation studies	6/89

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 6 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.3.3	Decision on vertical and horizontal emplacement orientation (continued)	C	Select waste package emplacement orientation	9/89
1.11.3.4	Development of a drainage and moisture control plan	A	Underground facility moisture control plan available to DOE	8/89
		B	Update of underground facility mositure control plan available to Information Need 4.4.5 (reference postclosure repository design)	2/93
		C	Draft of final report on the underground facility moisture control plan available to DOE	12/93
1.11.3.5	Development of contingency plan criteria	A	Input available site, design, and performance assessment information necessary to complete criteria development for contingency plan	6/89
		B	Underground facility contingency plan available to DOE	8/90
		C	Complete update of underground facility contingency plan	1/92

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 7 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.3.5	Development of contingency plan criteria (continued)	D	Update of underground facility contingency plan available to Information Need 4.4.5 (reference postclosure repository design)	2/93
		E	Draft of final report on the underground facility contingency plan available to DOE	12/93
1.11.4.1	Evaluation of chemical changes resulting from the use of construction materials	A	Preliminary report available to DOE on the potential effects of construction materials on geochemistry	4/90
		B	Draft report available to DOE on expected chemical changes resulting from the use of construction materials	11/91
		C	Update of expected chemical changes resulting from the use of construction materials available	2/93
		D	Draft of final report on chemical changes from construction materials available to DOE	12/93

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 8 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.4.2	Development of material inventory criteria	A	Complete development of preliminary underground facility material inventory criteria	12/90
		B	Complete development of material inventory criteria for start of LAD	2/92
		C	Update of material inventory criteria available to Information Need 4.4.5 (reference postclosure repository design)	3/93
		D	Draft of final report on material inventory criteria available to DOE	1/94
1.11.4.3	Development of water management criteria	A	Complete preliminary water management criteria development	9/89
		B	Draft report available to DOE on water usage criteria	9/90
		C	Complete development of water usage criteria for the start of LAD	2/92
		D	Draft of final report on water management criteria available to DOE	12/93

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 9 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.5.1	Development of excavation methods criteria	A	Input available information on the disturbed zone and potential excavation methods needed for the development of excavation methods criteria	4/90
		B	Complete definition of underground facility excavation methods criteria	1/92
		C	Draft of final report on excavation methods criteria available to DOE	12/93
1.11.5.2	Development of long-term subsidence control strategy	A	Preliminary subsidence control strategy available	8/90
		B	Update of subsidence control strategy available	5/92
		C	Draft report available to DOE on the long-term subsidence control strategy	8/93
		D	Draft of final report on long-term subsidence control strategy available to DOE	4/94
1.11.6.1	Evaluation of thermal loading for the underground facility	A	Complete determination of allowable far-field areal power density for ACD	8/89

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 10 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.6.1	Evaluation of thermal loading for the underground facility (continued)	B	Complete determination of allowable far-field areal power density for LAD	2/91
		C	Complete update of allowable far-field areal power density and begin preparation of final report	2/93
		D	Draft of final report on allowable power density available to DOE	12/93
1.11.6.2	Development of borehole spacing strategy	A	Draft report available to DOE on the borehole spacing strategy for ACD	7/89
		B	Draft report available to DOE on equivalent energy density concept for ACD	9/89
		C	Draft report available to DOE on updated equivalent energy density concept for LAD	2/92
		D	Draft report available to DOE on the borehole spacing strategy for LAD	2/92
		E	Complete update and begin preparation of final update report on equivalent energy concept	3/93
		F	Final report on equivalent energy concept available to DOE	1/94

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 11 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.6.3	Sensitivity studies	A	Preliminary results of thermal/ mechanical sensitivity studies available for assessments of areal power density	5/89
		B	Complete ACD far-field thermo/ mechanical analysis sensitivity study	12/90
		C	Complete repository ACD near-field thermomechanical analysis sensitivity studies	12/90
		D	Complete LAD far-field thermomechanical analysis sensitivity study	1/94
		E	Complete LAD near-field thermomechanical analysis sensitivity study	1/94
1.11.6.4	Development of the strategy for containment enhancement	A	Complete strategy for underground facility design considerations to enhance containment	7/89
		B	Complete LAD strategy for underground facility designzconsiderations to enhance containment	10/91

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 12 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.6.4	Development of the strategy for containment enhancement (continued)	C	Draft of final report on design considerations to enhance containment	12/93
		D	Complete update of strategy and begin final update report on underground facility design considerations to enhance containment	1/94
1.11.6.5	Reference calculations	A	Begin near- and far-field reference calculations for ACD	1/90
		B	Complete ACD far-field reference design analysis calculations	7/91
		C	Complete ACD near-field reference design analysis calculations	7/91
		D	Complete LAD reference design calculations	5/94
1.11.7.1	Reference postclosure repository design	A	Begin reference postclosure design activities	1/90
		B	Complete reference postclosure design for ACD	11/90
		C	Draft design analysis report available to DOE on performance assessment of LAD	6/93

Table 8.3.2.2-15. Major events and planned completion dates for activities in Issue 1.11 (postclosure repository design) (page 13 of 13)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
1.11.7.1	Reference postclosure repository design (continued)	D	Design analysis report to support the license application available to DOE	8/94
1.11.7.2	Documentation of compliance	A	Begin reference postclosure design confirmation activities	9/89
		B	Complete reference ACD postclosure design confirmation	7/91
		C	Begin updating LAD postclosure design confirmation	8/93
		D	Complete reference LAD postclosure design confirmation	9/94

[a]The letters in this column key major events shown in Figure 8.3.2.2-3.

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.2.3, Repository Design Criteria for Radiological Safety

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.2.3 Issue resolution strategy for Issue 2.7: Have the characteristics and configurations of the repository been adequately established to (a) show compliance with the preclosure design criteria of 10 CFR 60.130 through 60.133 and (b) provide information for the resolution of the performance issues?

This issue is concerned with the features (i.e., characteristics and configurations) of the repository that relate to radiological safety. These features consist of a subset of the total set of engineered systems and components that make up the repository. The features also address some aspects of the natural setting (i.e., the site) by accounting for the impact of these aspects on the engineered systems and components. For example, the shielding properties of the host rock and their effect on radiation levels in areas occupied by workers should be considered in the design of equipment for handling the waste package in the underground facility.

The role of this issue in addressing the features of the repository related to radiological safety must be placed in context with the roles of other issues. Figure 8.3.2.1-1, Section 8.3.2.1, shows the relationships between several design and performance assessment issues. To be more specific about the relationship of Issue 2.7 to the other issues with which it is directly tied, only Issues 2.7 (this issue), 4.4 (Section 8.3.2.5), and 2.1 through 2.3 (Sections 8.3.5.3 through 8.3.5.5) are shown in Figure 8.3.2.3-1. The figure defines the ties between these issues by indicating what major items of information are passed between them. The figure also illustrates the connection of all these issues with the site characterization program. The scope of an issue is indicated by its size with respect to other issues in this figure. Note that Issue 4.4 is the largest in scope, and the other issues, including this issue branch out from Issue 4.4, reducing the scope to more specific areas. A strong tie between Issue 2.7 and Issue 4.4 is indicated and, in particular, the reliance of this issue upon Issue 4.4 for development of the design and supporting analyses.

In the discussion that follows in this section, the regulatory basis for addressing Issue 2.7 is described, the approach to resolving the issue is defined, and the relationship of this approach with the information needs within this issue is discussed.

Regulatory basis for the issue

As indicated in this issue statement, the regulatory bases for this issue arise primarily from two sources. First, 10 CFR Part 60 provides the repository design criteria in Sections 60.131 through 60.133. In addition, 10 CFR 60.111(a) and 10 CFR Part 20 are pertinent to this issue. Performance Issues 2.1, 2.2, and 2.3, which address radiological exposures to the workers and public under normal and accident conditions, impose criteria upon the design of the repository as a result of EPA and NRC imposed limits on the exposures to the public and workers. These two bases for Issue 2.7 will be treated individually and in detail in the discussions that follow.

In 10 CFR Part 60 the NRC has laid out design criteria for the geologic repository and the waste package. These criteria are found in Sections 60.130 through 60.135. In addition to the brief statement of the general scope of the design criteria given in section 60.130, the sections of

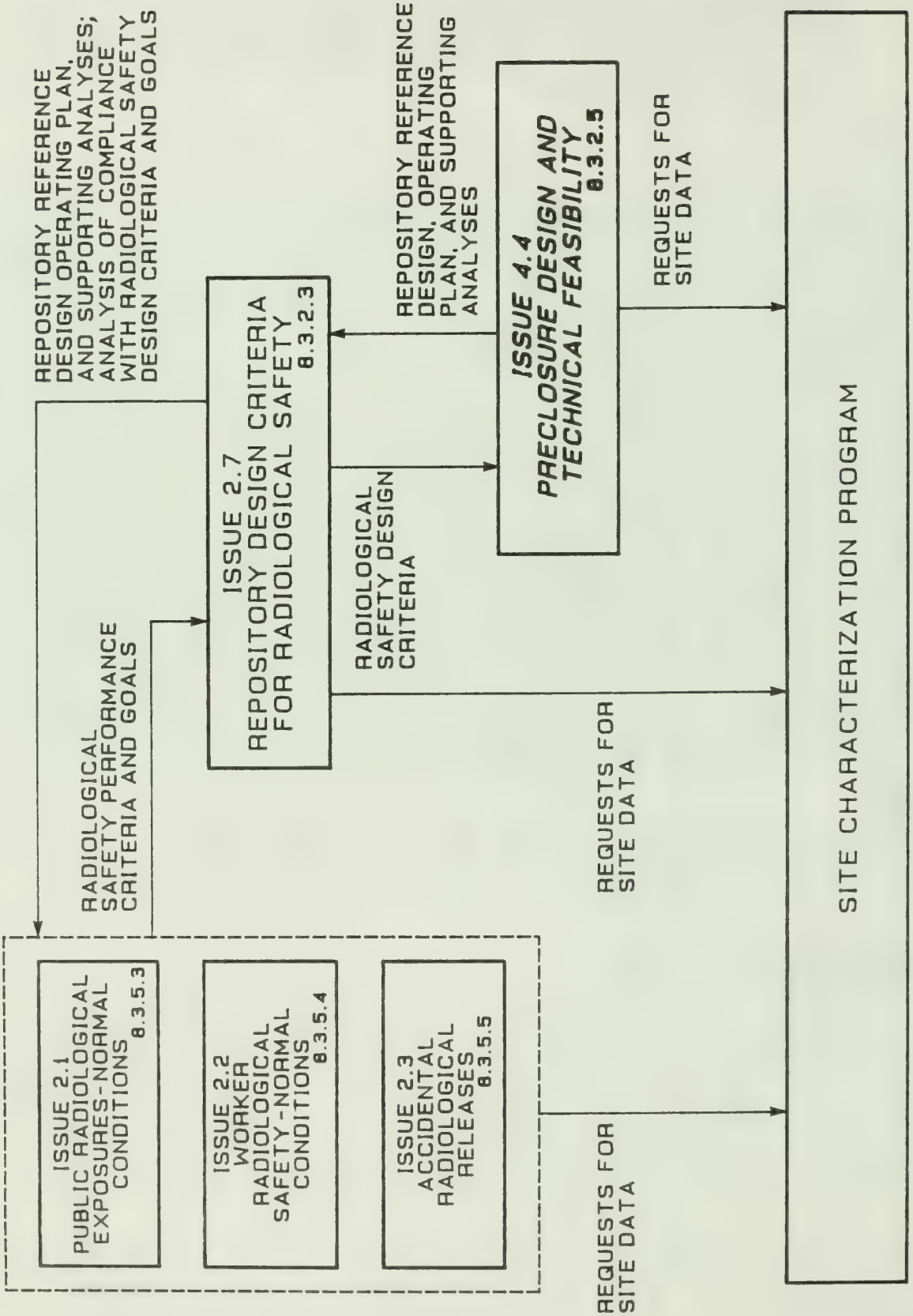


Figure 8.3.2.3-1. Relationship of Issue 2.7 (repository design criteria for radiological safety) to other issues and the site characterization program.

particular importance to repository design aspects of radiological safety are 60.131 through 60.133. (Section 60.134 addresses seals and is treated in Section 8.3.3, seals systems. Section 60.135 is treated in Section 8.3.4 under Issue 2.6, waste package characteristics--preclosure.) General design criteria for the geologic repository operations area (GROA) are given in 10 CFR 60.131. This section contains two main topics: (1) methods of radiological protection and (2) systems, structures, and components important to safety. Additional design criteria for the surface facilities are given in 60.132, and additional design criteria for the underground facilities are given in 60.133.

Not all the design criteria spelled out in these sections are related to radiological safety; therefore, not all these design criteria are addressed in Issue 2.7. The division of responsibility and relationships between the design issues are described in Section 8.3.2.1 (Figure 8.3.2.1-1), and the specific issue responsible for addressing each criterion stated in 10 CFR 60.131 through 60.133 is presented in Table 8.3.2.3-1. In addition, the table also indicates which of the criteria result in the need for site parameters in order to accomplish the design and analyses necessary to address the criteria. Only those criteria that result in the need for site data will be addressed in detail in the SCP. All criteria, as well as the plans to account for those criteria in the design of the repository, will be addressed in the plans for repository design.

Approach to resolving the issue

Licensing strategy overview

This issue requires that the repository design incorporate the general design criteria specified in 10 CFR 60.131 through 60.133 such that the preclosure performance objectives identified in 10 CFR 60.111 can be met. The general objective of these criteria is to ensure that the geologic repository operations area (GROA) is designed in such a way that the general public and repository workers are adequately protected from both routine and accidental releases of radioactive material during repository operation, including retrieval operations. The primary means of resolving this issue is by reflecting the preclosure design criteria of 10 CFR 60.131 through 60.133 in the design of the GROA and by performing analyses that will demonstrate that the performance objectives of 10 CFR 60.111 will be met.

As stated in 10 CFR 60.130, the design criteria specified in 10 CFR 60.131 through 60.133 are a minimum set. Other design criteria may be specified that are consistent with and complement the criteria in 10 CFR 60.131 through 60.133. As can be seen in Table 8.3.2.3-1, the information needed to resolve this issue is primarily design related. Site data that are required pertain mainly to the identification of design-basis accidents and to the use of the site properties to help design features enhance radiological safety. The resolution of Issue 2.7 will be complete when it has been demonstrated that each item listed in 10 CFR 60.131 through 60.133 has been adequately addressed in the license application design. The analysis of additional design features will provide added assurance of radiological safety beyond the regulatory requirements. It is important to note that under this issue, assurance will be provided that radiation safety design criteria are met

Table 8.3.2.3-1. Design criteria for the geologic repository operations area (page 1 of 8)

Design criteria of 10 CFR 60.131 through 60.133	Issue that addresses the criterion[b]	Are the site data needed to address the criterion?
60.131 GENERAL DESIGN CRITERIA FOR THE GEOLOGIC REPOSITORY OPERATIONS AREA		
(a) Radiological protection. The geologic repository operations area shall be designed to maintain radiation doses, levels, and concentrations of radioactive material in air in restricted areas within the limits specified in Part 20 of this chapter. Design shall include -		
(1) Means to limit concentrations of radioactive material in air;	2.7	Yes
(2) Means to limit the time required to perform work in the vicinity of radioactive materials, including, as appropriate, designing equipment for ease of repair and replacement and providing adequate space for ease of operation;	2.7	No
(3) Suitable shielding;	2.7	Yes
(4) Means to monitor and control the dispersal of radioactive contamination;	2.7	Yes
(5) Means to control access to high radiation areas or airborne radioactivity areas; and	2.7	No
(6) A radiation alarm system to warn of significant increases in radiation levels, concentrations of radioactive material in air, and of increased radioactivity released in effluents. The alarm system shall be designed with provisions for calibration and for testing its operability.	2.7	Yes
(b) Structures, systems, and components important to safety.		
(1) Protection against natural phenomena and environmental conditions.	2.7	Yes
The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the geologic repository operations area will not interfere with necessary safety functions.		

Table 8.3.2.3-1. Design criteria for the geologic repository operations area (page 2 of 8)

Design criteria of 10 CFR 60.131 through 60.133	Issue that addresses the criterion[b]	Are the site data needed to address the criterion?
60.131 GENERAL DESIGN CRITERIA FOR THE GEOLOGIC REPOSITORY OPERATIONS AREA (continued)		
(2) Protection against dynamic effects of equipment failure and similar events.	2.7	No
The structures, systems, and components important to safety shall be designed to withstand dynamic effects such as missile impacts, that could result from equipment failure, and similar events and conditions that could lead to loss of their safety functions.		
(3) Protection against fires and explosions.		
(i) The structures, systems, and components important to safety shall be designed to perform their safety functions during and after credible fires or explosions in the geologic repository operations area.	2.7	Yes
(ii) To the extent practicable, the geologic repository operations area shall be designed to incorporate the use of noncombustible and heat resistant materials.	4.4	No
(iii) The geologic repository operations area shall be designed to include explosion and fire detection alarm systems and appropriate suppression systems with sufficient capacity and capability to reduce the adverse effects of fires and explosions on structures, systems, and components important to safety.	2.7	Yes
(iv) The geologic repository operations area shall be designed to include means to protect systems, structures, and components important to safety against the adverse effects of either the operation or failure of the fire suppression systems.	2.7	No
(4) Emergency capability.		
(i) The structures, systems, and components important to safety shall be designed to maintain control of radioactive waste and radioactive effluents, and permit prompt termination of operations and evacuation of personnel during an emergency.	2.7	No

Table 8.3.2.3-1. Design criteria for the geologic repository operations area (page 3 of 8)

Design criteria of 10 CFR 60.131 through 60.133	Issue that addresses the criterion[b]	Are the site data needed to address the criterion?
60.131 GENERAL DESIGN CRITERIA FOR THE GEOLOGIC REPOSITORY OPERATIONS AREA (continued)		
(ii) The geologic repository operations area shall be designed to include onsite facilities and services that ensure a safe and timely response to emergency conditions and that facilitate the use of available offsite services (such as fire, police, medical, and ambulance service) that may aid in recovery from emergencies.	4.4	No
(5) Utility services.		
(i) Each utility service system that is important to safety shall be designed so that essential safety functions can be performed under both normal and accident conditions.	2.7	Yes
(ii) The utility services important to safety shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform their safety functions.	2.7	No
(iii) Provisions shall be made so that, if there is a loss of the primary electric power source or circuit, reliable and timely emergency power can be provided to instruments, utility service systems, and operating systems, including alarm systems, important to safety.	2.7	No
(6) Inspection, testing, and maintenance.	2.7	No
The structures, systems, and components important to safety shall be designed to permit periodic inspection, testing, and maintenance, as necessary, to ensure their continued functioning and readiness.		
(7) Criticality control.	2.7	Yes
All systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated		

Table 8.3.2.3-1. Design criteria for the geologic repository operations area (page 4 of 8)

Design criteria of 10 CFR 60.131 through 60.133	Issue that addresses the criterion[b]	Are the site data needed to address the criterion?
60.131 GENERAL DESIGN CRITERIA FOR THE GEOLOGIC REPOSITORY OPERATIONS AREA (continued)		
effective multiplication factor (k_{eff}) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.		
(8) Instrumentation and control systems.	2.7	Yes
The design shall include provisions for instrumentation and control systems to monitor and control the behavior of systems important to safety over anticipated ranges for normal operations and for accident conditions.		
(9) Compliance with mining regulations.	2.7, 4.2	Yes
To the extent that DOE is not subject to the Federal Mine Safety and Health Act of 1977, as to the construction and operation of the geologic repository operations area, the design of the geologic repository operations area shall nevertheless include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions. Any deviation from relevant design requirements in 30 CFR, Chapter 1, Subchapters D, E, and N will give rise to a rebuttable presumption that this requirement has not been met.		
(10) Shaft conveyances used in radioactive waste handling.	NA[b] - all waste will be transported underground using a ramp[c]	NA
(i) Hoists important to safety shall be designed to preclude cage free fall.		
(ii) Hoists important to safety shall be designed with a reliable cage location system.		NA
(iii) Loading and unloading systems for hoists important to safety shall be designed with a reliable system of interlocks that will fail safely upon malfunction.	NA	NA

Table 8.3.2.3-1. Design criteria for the geologic repository operations area (page 5 of 8)

Design criteria of 10 CFR 60.131 through 60.133	Issue that addresses the criterion[b]	Are the site data needed to address the criterion?
60.131 GENERAL DESIGN CRITERIA FOR THE GEOLOGIC REPOSITORY OPERATIONS AREA (continued)		
(iv) Hoists important to safety shall be designed to include two independent indicators to indicate when waste packages are in place and ready for transfer.	NA	NA
60.132 ADDITIONAL DESIGN CRITERIA FOR SURFACE FACILITIES IN THE GEOLOGIC REPOSITORY OPERATIONS AREA		
(a) Facilities for receipt and retrieval of waste.	2.7	Yes
Surface facilities in the geologic repository operations area shall be designed to allow safe handling and storage of wastes at the geologic repository operations area, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility.		
(b) Surface facility ventilation.	2.7	Yes
Surface facility ventilation systems supporting waste transfer, inspection, decontamination, processing, or packaging shall be designed to provide protection against radiation exposure and offsite releases as provided in 60.111(a).		
(c) Radiation control and monitoring.		
(1) Effluent control.	2.7	Yes
The surface facilities shall be designed to control the release of radioactive materials in effluents during normal operations so as to meet the performance objectives of 60.111(a).		
(2) Effluent monitoring.	2.7	No
The effluent monitoring systems shall be designed to measure the amount and concentration of radionuclides in any effluent with sufficient precision to determine whether releases conform to the design requirement for effluent control. The monitoring systems shall be designed to include alarms that can be periodically tested.		

Table 8.3.2.3-1. Design criteria for the geologic repository operations area (page 6 of 8)

Design criteria of 10 CFR 60.131 through 60.133	Issue that addresses the criterion[b]	Are the site data needed to address the criterion?
60.132 ADDITIONAL DESIGN CRITERIA FOR SURFACE FACILITIES IN THE GEOLOGIC REPOSITORY OPERATIONS AREA (continued)		
(d) Waste treatment.	2.7	No
Radioactive waste treatment facilities shall be designed to process any radioactive wastes generated at the geologic repository operations area into a form suitable to permit safe disposal at the geologic repository operations area or to permit safe transportation and conversion to a form suitable for disposal at an alternative site in accordance with any regulations that are applicable.		
(e) Consideration of decommissioning.	4.4	No
The surface facility shall be designed to facilitate decontamination or dismantlement to the same extent as would be required, under other parts of this chapter, with respect to equivalent activities licensed thereunder.		
60.133 ADDITIONAL DESIGN CRITERIA FOR THE UNDERGROUND FACILITY		
(a) General criteria for the underground facility.		
(1) The orientation, geometry, layout, and depth of the underground facility, and the design of any engineered barriers that are part of the underground facility shall contribute to the containment and isolation of radionuclides.	1.11	Yes
(2) The underground facility shall be designed so that the effects of credible disruptive events during the period of operations, such as flooding, fires, and explosions will not spread through the facility.	4.4	No
(b) Flexibility of design.		
The underground facility shall be designed with sufficient flexibility to allow adjustments where necessary to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.	1.11	Yes

Table 8.3.2.3-1. Design criteria for the geologic repository operations area (page 7 of 8)

Design criteria of 10 CFR 60.131 through 60.133	Issue that addresses the criterion[b]	Are the site data needed to address the criterion?
60.133 ADDITIONAL DESIGN CRITERIA FOR THE UNDERGROUND FACILITY (continued)		
(c) Retrieval of waste.	2.4, 4.4	Yes
The underground facility shall be designed to permit retrieval of waste in accordance with the performance objectives of 60.111.		
(d) Control of water and gas.	4.4	Yes
The design of the underground facility shall provide for control of water or gas intrusion.		
(e) Underground openings.		
(1) Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained.	2.4, 4.2, 4.4	Yes
(2) Openings in the underground facility shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock.	1.11	Yes
(f) Rock excavation.	1.11	Yes
The design of the underground facility shall incorporate excavation methods that will limit the potential for creating a preferential pathway for ground water or radioactive waste migration to the accessible environment.		
(g) Underground facility ventilation.		
The ventilation system shall be designed to -		
(1) Control the transport of radioactive particulates and gases within and releases from the underground facility in accordance with the performance objectives of 60.111(a).	2.7	Yes
(2) Assure continued function during normal operations and under accident conditions.	2.7, 4.2, 4.4	Yes
(3) Separate the ventilation of excavation and waste emplacement areas.	2.7,4.4	No

Table 8.3.2.3-1. Design criteria for the geologic repository operations area (page 8 of 8)

Design criteria of 10 CFR 60.131 through 60.133	Issue that addresses the criterion[b]	Are the site data needed to address the criterion?
60.133 ADDITIONAL DESIGN CRITERIA FOR THE UNDERGROUND FACILITY (continued)		
(h) Engineered barriers.	1.11	Yes
Engineered barriers shall be designed to assist the geologic setting in meeting the performance objectives for the period following permanent closure.		
(i) Thermal loads.	1.11	Yes
The underground facility shall be designed so that the performance objectives will be met taking into account the predicted thermal and thermomechanical response of the host rock, and surrounding strata, ground-water system.		

[a]The SCP sections addressing the issues listed in this column are as follows: Issue 1.11, configuration of underground facilities (postclosure)(Section 8.3.2.2); Issue 2.4, waste retrievability (Section 8.3.5.2); Issue 2.7 (this section); Issue 4.2, nonradiological health and safety (Section 8.3.2.4); and Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5).

[b]NA = not applicable.

[c]The Yucca Mountain Project has a ramp instead of a hoist, which will be used to transport waste underground in transporters. Accidents involving the transport of waste underground, such as a runaway transporter, are being investigated.

while Performance Issues 2.1 through 2.3 will address compliance with regulatory limits. (Note that there are currently no regulatory dose limits for repository accidents.)

Application of the issue resolution strategy

The logic to be used in the resolution of this issue is illustrated in the logic diagram shown in Figure 8.3.2.3-2. This diagram depicts how the generic approach to issue resolution described in Section 8.1 and 8.2 is to be applied to this issue. The first step of this process, identifying regulatory requirements, has already been discussed previously under "regulatory basis for the issue." The following discussions will explain each of the remaining steps shown in the logic diagram for the resolution of this issue.

Identification of functional requirements. To allocate performance to the engineered systems of the Yucca Mountain mined geological disposal system (MGDS), the functions of the MGDS with respect to this issue must be identified. These functions of the MGDS may be taken from Table 8.3.2.3-1. These functions and what might be called subfunctions are listed below with some elaboration on each. The portion of 10 CFR 60.131 through 60.133 that the function or subfunction is intended to address is also listed in parentheses.

Function 1: Radiological protection. The first function of the repository is to maintain radiation doses, levels, and concentrations of radioactive material in restricted areas within the limits specified in 10 CFR Part 20. This function is intended to produce a design that will protect the radiological health and safety of both the repository workers and the public. Radiological protection involves many activities; therefore, it has been subdivided into 11 subfunctions. These subfunctions are labeled with letters that correspond to the designators used in the performance goal and parameters tables presented later in this section and are as follows:

A. Limit concentration of radioactive materials in air (10 CFR 60.131(a)(1)).

B. Limit time required to perform work in the vicinity of radioactive materials (10 CFR 60.131(a)(2)).

C. Provide suitable shielding where necessary (10 CFR 60.131 (a)(3)).

D. Monitor and control the dispersal of radioactive contamination (10 CFR 60.131(a)(4)).

E. Control access to high radiation areas (10 CFR 60.131(a) (5)).

F. Provide radiation alarm systems for worker protection (10 CFR 60.131(a)(6)).

G. Monitor and control radioactive materials in repository effluents (10 CFR 60.132(c)).

H. Provide radiation alarm systems for repository effluents (10 CFR 60.131(a)(6)).

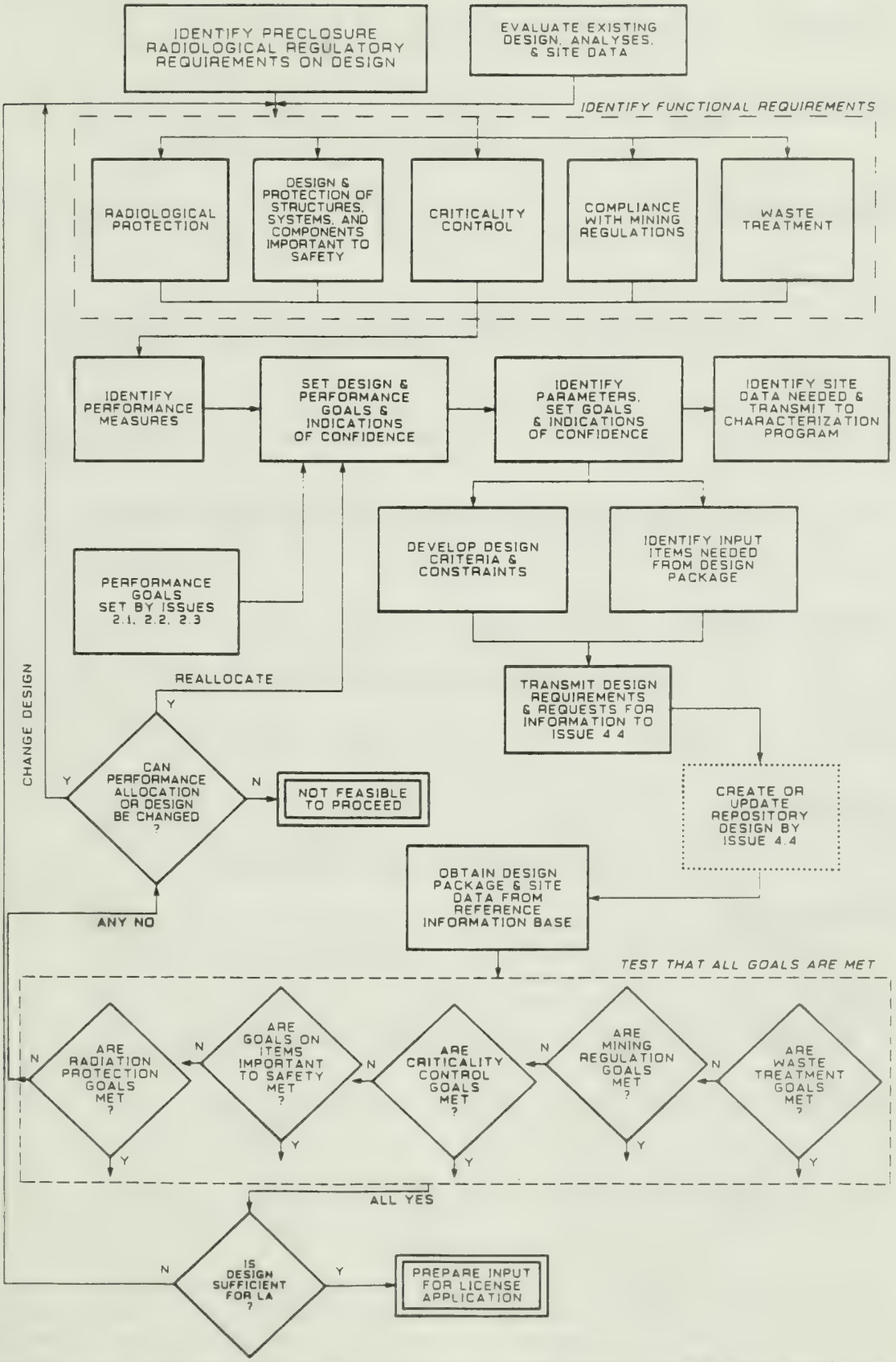
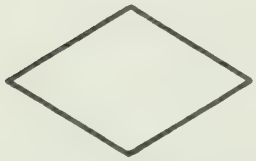


Figure 8.3.2.3-2a. Logic diagram for Issue 2.7 (repository design criteria for radiological safety). See Figure 8.3.2.3-2b for legend. Section 8.3.2.1 describes the relationships and interfaces between design and perfromance issues.

LEGEND



ACTIVITY PERFORMED TO RESOLVE ISSUE



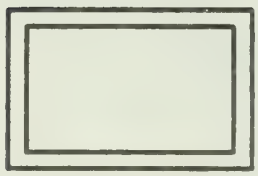
TEST TO DETERMINE SUBSEQUENT ACTIVITY



ACTIVITY PERFORMED BY INDICATED ISSUE



ACTIVITY WITH MULTIPLE SIMILAR ACTIVITIES OR TESTS



DECISION ABOUT ISSUE RESOLUTION

Y - YES N - NO LA - LICENSE APPLICATION

Figure 8.3.2.3-2b. Legend for Figure 8.3.2.3-2a.

I. Provide safe handling and storage of waste whether awaiting emplacement or being retrieved (10 CFR 60.132 (a)).

J. Provide repository facility ventilation systems that will protect against radiation exposure (10 CFR 60.132 (b) and 10 CFR 60.133 (g)).

K. Assure the continued function and separation of ventilation systems during normal operations and under accidents conditions (10 CFR 60.132(b) and 10 CFR 60.133(g)).

Function 2: Design and protection of structures, systems, and components (SS&C) important to safety (ITS). This function is intended to produce a design that provides assurance that radiation safety design features will operate effectively when they are needed. This function also involves many activities and has been subdivided into eight subfunctions. These eight subfunctions are also labeled with the letter designators used later in this section and are as follows:

L. Protect structures, systems, and components important to safety against natural phenomena and environmental conditions (e.g., rockburst) (10 CFR 60.131(b)(1)).

M. Protect structures, systems, and components important to safety against dynamic effects of equipment failure and similar events (10 CFR 60.131(b)(2)).

N. Protect structures, systems, and components important to safety against fires and explosions (10 CFR 60.131(b)(3)).

O. Ensure that structures, systems, and components important to safety will maintain control of radioactive materials, permit prompt termination of operations, and allow evacuation of personnel during an emergency (10 CFR 60.131(b)(4)(i)).

P. Ensure that utilities important to safety will continue their safety functions during emergencies (10 CFR 60.131(b)(5)).

Q. Ensure that structures, systems, and components important to safety will facilitate inspection, testing, and maintenance (10 CFR 60.131(b)(6)).

R. Provide timely backup power when needed and during emergencies (10 CFR 60.131(b)(5)).

S. Provide instrumentation and control systems to monitor and control structures, systems, and components important to safety for all anticipated ranges of operation (10 CFR 60.131(b)(8)).

Function 3: Criticality control. This function will provide assurance that all systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive material are designed to ensure that a criticality accident is not credible (10 CFR 60.131(b)(7)).

Function 4: Compliance with mining regulations. This function will ensure that requirements of 30 CFR Chapter I, Subchapters D, E, and N that are applicable to protection of workers who perform a safety function will be incorporated into the design of the repository (10 CFR 60.131(b)(9)).

Function 5: Waste treatment. This function will ensure that waste treatment facilities are designed to permit safe offsite disposal of site-generated waste in accordance with applicable regulations (10 CFR 60.132(d)).

Allocation of performance. The next four steps after the identification of functional requirements include the bulk of the performance allocation process. In these steps, performance measures, performance goals, and needed parameters are developed. The results of these steps are in Tables 8.3.2.3-2 and 8.3.2.3-3.

The functions that organize these tables were derived directly from 10 CFR 60.131 through 60.133. Performance measures developed for each function provide the means to measure success in performing the required functions. Performance goals were developed such that if the goals are met, the function is satisfactorily completed. The parameters listed in Table 8.3.2.3-3 for each performance goal are those site data needed to calculate the performance measure to be compared with the performance goal.

Development of design criteria and constraints. This issue develops design objectives and criteria to be used by Issue 4.4 (preclosure design and technical feasibility) in designing the repository. These design objectives are listed as performance goals in Table 8.3.2.3-2. In general, the basis for developing numerical performance goals has been to assume one-fifth of the limits specified in DOE Order 5480.1, Chapter XI (DOE, 1980). Of all these performance goals, a few stand out as the major design objectives for radiological safety. The first of these comes out of the shielding function and establishes that radiation fields in all normally occupied areas (or areas to which workers have free access) shall be less than 0.5 mrem/h. Any areas of the repository with radiation fields that cannot be reduced to below 0.5 mrem/h shall have controlled access and other procedural controls to limit doses to workers. Another design objective is that concentrations of airborne radionuclides (including radon and short-lived radon daughters) shall be as low as reasonably achievable (ALARA) below a design objective of one-fifth the values listed in 10 CFR 20, Appendix B, Table I, Column I. (Since radon is a naturally occurring radionuclide, it is not strictly within the scope of 10 CFR Part 20 or Subpart A of 40 CFR Part 191; however, radon releases are considered within the scope of this issue.) A third important design objective is the requirement to maintain releases of radioactive materials in repository effluents below levels that would result in offsite individual 50-yr whole-body dose equivalents of 25 mrem/yr (40 CFR 191.03). This value is considered to embody the ALARA principle (Kathren et al., 1980). A final design objective is to maintain combined annual individual worker doses from all sources of radiation to less than 1 rem if consistent with NRC ALARA requirements. To be consistent with the ALARA principle, lower levels of radiation will be achieved if it is reasonable to do so. It should be noted that based on International Committee on Radiation Protection, Publications 26 and 30 (ICRP, 1977; 1978), current regulations are undergoing changes that may require changes in these design criteria.

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 1 of 13)

Subfunction	Process or activity	Performance measure		Tentative goal	Needed confidence	Site data?
RADIOLOGICAL PROTECTION (FUNCTION 1)						
A Limit concentrations of radioactive materials in air	Monitor concentrations of radioactive materials in repository airstreams	Concentrations of radioactive materials in repository airstreams	A1	Concentrations of radioactive materials in normally occupied areas do not exceed 20% of the values listed in in 10 CFR 20, Appendix B, Table 1, Column 1	(a)	No
			A2	Concentrations of non-naturally occurring radioactive materials in controlled access areas do not exceed the values listed in 10 CFR 20, Appendix B, Table 1, Column 1	High	Yes
			A3	Concentrations of naturally occurring radon and short-lived radon daughters such that annual exposure is less than 4 Working Level Months as defined in 30 CFR 57.2	High	Yes
	Filter exhaust air from potentially contaminated areas	Concentrations of radioactive materials in repository airstreams		See A1, A2, and A3 above	High	Yes
	Maintain gaseous radionuclides in repository airstreams below acceptable levels	Concentrations of radioactive materials in repository airstreams		See A1, A2, and A3 above	High	Yes

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 2 of 13)

Subfunction	Process or activity	Performance measure	Tentative goal	Needed confidence	Site data?
RADIOLOGICAL PROTECTION (FUNCTION 1) (continued)					
B Limit time required to perform work in the vicinity of radioactive materials	Limit time of occupancy for tasks in radiation fields greater than 0.5 mrem/h	Time required to perform tasks in radiation fields greater than 0.5 mrem/h	B1 Time limited such that the as low as reasonably achievable (ALARA) principle is met	(a)	No
			B2 Combined annual individual worker dose less than 1 rem by as much as reasonable	(a)	No
	Provide remote handling capability for long-term task in radiation fields greater than 0.5 mrem/h	Dose reduction due to use of remote handling equipment	B3 Dose reduction enough to justify use of remote handling equipment	(a)	No
C Provide suitable shielding materials	Provide shielding to reduce radiation fields to below 0.5 mrem/h in normally occupied work areas	Radiation fields in normally occupied work areas	C1 Radiation fields less than 0.5 mrem/h by as much as is reasonable	(a)	No
	Utilize shielding properties of the host rock in limiting exposure of workers to direct radiation	Dose reduction factor attributable to host rock shielding properties	C2 Dose reduction factor properties similar to concrete	Medium	Yes
D Monitor and control the dispersal of radioactive contamination	Monitor contamination by using				
	- Stationary radiation monitoring systems	Contamination levels outside contamination areas	D1 Doses due to contamination insignificant	(a)	No

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 3 of 13)

Subfunction	Process or activity	Performance measure	Tentative goal	Needed confidence	Site data?
		RADIOLOGICAL PROTECTION (FUNCTION 1) (continued)			
D Monitor and control the dispersal of radioactive contamination (continued)	- Portable radiation monitors	Contamination levels outside contamination areas	D2 Doses due to contamination insignificant	High	Yes
	- Personnel dosimetry	Contamination on personnel	D3 Doses due to contamination insignificant	(a)	No
	Control dispersal of contamination by				
	- Providing access control to potential contamination areas	See subfunction E, performance measures	D4 See subfunction E, goals	(a)	No
	- Providing ventilation control and cleanup of airstreams	See subfunction J, performance measures	D5 See subfunction J, goals	High	Yes
	- Decontamination of contaminated items and equipment	Residual contamination	D6 Use Regulatory Guide 1.86 (NRC, 1974), methods and meet goals	(a)	No
	- Collection of site-generated waste	Residual contamination due to site-generated waste	D7 No residual contamination	(a)	No

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 4 of 13)

Subfunction	Process or activity	Performance measure		Tentative goal	Needed confidence	Site data?
RADIOLOGICAL PROTECTION (FUNCTION 1) (continued)						
E Control access to high radiation areas	Provide signs and personnel barriers to prevent access by unauthorized personnel	Visibility of signs	E1	Compliance with 10 CFR 20.203	(a)	No
			E2	Adequate visibility	Medium	No
		Distribution and location of signs	E3	Compliance with 10 CFR 20.203	(a)	No
			E4	Adequate distribution	(a)	No
		Effectiveness of personnel barriers	E5	Adequate barrier effectiveness	(a)	No
	If necessary, provide guards to prevent access by unauthorized personnel	Effectiveness of guard	E6	No unauthorized access	(a)	No
	Provide procedural requirements to control access to high radiation areas	Effectiveness of procedures	E7	Adequate procedures to control access	(a)	No
F Provide radiation alarm systems for worker protection	Provide visual alarm systems to alert workers if radiation levels exceed established design levels	Visibility of alarm system	F1	Adequate visibility	(a)	No
		Accuracy and reliability of alarm system	F2	Adequate accuracy and reliability of alarm system	(a)	No

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 5 of 13)

Subfunction	Process or activity	Performance measure	Tentative goal	Needed confidence	Site data?
RADIOLOGICAL PROTECTION (FUNCTION 1) (continued)					
F Provide radiation alarm systems for worker protection (continued)	Provide audible alarm systems to alert workers if radiation levels exceed established design levels	Loudness and noticeability of alarm system	F3 Consistency with Regulatory Guide 8.5 (NRC, 1981b)	(a)	No
		Accuracy and reliability of alarm system	F4 Adequate accuracy and reliability of alarm system	(a)	No
G Monitor and control radioactive materials in repository effluents	Detect radioactive materials in repository effluents streams	Ability to detect radioactive materials in repository effluent streams	G1 Adequate detection of significant radionuclides in repository effluents	(a)	No
			G2 Detection precision consistent with industry standard and adequate to demonstrate compliance with goals	(a)	No
	Control radioactive materials in repository effluent streams	Ability to control radioactive materials in repository effluent streams	G3 Adequate control of significant radionuclides in repository effluents	(a)	No
			G4 Maintain releases of radioactive materials at or below levels that would result in offsite individual 50-yr dose equivalents of 25 mrem/yr (see page 8.10 of ALARA guide; Kathren et al., 1980)	High	Yes
H Provide radiation alarm systems for repository effluents	Provide visual alarm systems to alert workers if radiation levels in effluents exceed established design levels	See subfunction F, performance measures	H1 See subfunction F, goals	(a)	No

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 6 of 13)

Subfunction	Process or activity	Performance measure	Tentative goal	Needed confidence	Site data?
RADIOLOGICAL PROTECTION (FUNCTION 1) (continued)					
H Provide radiation alarm systems for repository effluents (continued)	Provide audible alarm systems to alert workers if radiation levels in effluents exceed established design levels	See subfunction F, performance measures	H2 See subfunction F, goals	(a)	No
I Provide safe handling and temporary storage of waste whether awaiting emplacement or being retrieved	See subfunction B, limit work time in vicinity of radioactive materials	See subfunction B, performance measures	I1 See subfunction B, goals	(a)	No
	See subfunction C, provide suitable shielding	See subfunction C, performance measures	I2 See subfunction C, goals	High	Yes
	Maintain combined individual worker doses from all sources of radiation below annual design objective	Combined annual individual worker doses from all sources of radiation	I3 Combined annual individual worker doses from all sources of radiation less than 1 rem and ALARA	(a)	No
J Provide repository facility ventilation systems that will protect against radiation exposure	Maintain airflow in direction from areas of lower contamination potential to areas of higher contamination potential	Pressure differentials between radiation zones	J1 Between 0.1 and 0.5 in. WG	High	Yes
		Potential for accidental flow reversals	J2 Accidental flow reversal precluded	(a)	No
		Flow rate in highly contaminated areas	J3 Adequate room changes per hour in areas of highest contamination per hour (e.g., isolation zones and hot cells)	(a)	No

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 7 of 13)

Subfunction	Process or activity	Performance measure		Tentative goal	Needed confidence	Site data?
RADIOLOGICAL PROTECTION (FUNCTION 1) (continued)						
J Provide repository facility ventilation systems that will protect against radiation exposure (continued)	Separate ventilation systems of surface waste-handling areas from other surface areas	Leakage between systems	J4	Very low leakage	(a)	No
		Pressure differential between separate systems	J5	Between 0.1 and 0.5 in. WG	(a)	No
	Separate ventilation systems of underground waste-handling and emplacement areas from mining development areas	Leakage between systems	J6	Very low leakage	(a)	No
		Pressure differential between separate systems	J7	Between 0.1 and 0.5 in. WG	(a)	No
	Provide close-capture ventilation exhaust systems when necessary	System capture efficiency	J8	Adequate capture efficiency	(a)	No
	Filter airstream and exhausts when necessary	Decontamination factor	J9	Adequate decontamination factor	High	Yes
		Number of filter banks	J10	Single stage available for normally clean areas	High	Yes
			J11	Two stage in service for expected contamination areas	(a)	No
	Flow pattern of ventilation should direct potential contamination away from personnel	Flow patterns of ventilation systems	J12	Potential contamination always directed away from personnel and to filterable exhausts	(a)	No

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 8 of 13)

	Subfunction	Process or activity	Performance measure		Tentative goal	Needed confidence	Site data?
	DESIGN AND PROTECTION OF STRUCTURES, SYSTEMS, AND COMPONENTS IMPORTANT TO SAFETY (FUNCTION 2)						
K	Protect structures, systems, and components important to safety against natural phenomena and environmental conditions	House structures, systems, and components important to safety in buildings designed to withstand credible natural phenomena and environmental conditions	Effects of credible natural phenomena and natural conditions on structures, systems, and components important to safety	K1	Structures, systems, and components function as designed to meet radiological dose limits	High	Yes
L	Protect structures, systems, and components important to safety against dynamic effects of equipment failure and similar events	House structures, systems, and components important to safety in structures designed to withstand dynamic effects of equipment failures and similar events	Response of structures, systems, and components important to safety to dynamic effects of equipment failure and similar events	L1	Structures, systems, and components function as designed to meet radiological dose limits	(a)	No
M	Protect structures, systems, and components important to safety against fires and explosions	House structures, systems, and components important to safety in structures with fire and explosion detection/suppression equipment	Effects of fires, explosions, and suppression systems on structures, systems, and components important to safety	M1	Structures, systems, and components function as designed to meet radiological dose limits	(a)	No

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 9 of 13)

	Subfunction	Process or activity	Performance measure		Tentative goal	Needed confidence	Site data?
	DESIGN AND PROTECTION OF STRUCTURES, SYSTEMS, AND COMPONENTS IMPORTANT TO SAFETY (FUNCTION 2) (continued)						
N	Ensure that structures, systems, and components important to safety will maintain control of radioactive materials, permit prompt termination of operations, and allow evacuation of personnel during emergencies	Design structures, systems, and components important to safety to maintain control of radioactive material during emergencies	Maintenance of control of radioactive material during design-basis accidents	N1	Control of radioactive material maintained such that dose limits are met	(a)	No
		Design structures, systems, and components important to safety to permit prompt shutdown of nonsafety related operations during an emergency	Time to shutdown non-safety related operations during design-basis accidents	N2	Prompt shutdown of non-safety related operations during design-basis accidents	(a)	No
		Design structures, systems, and components important to safety so that they facilitate the evacuation of the repository during emergencies	Effects of structures, systems, and components important to safety on evacuation during an emergency	N3	Minimal effect of structures, systems, and components important to safety on evacuation of personnel	(a)	No
O	Ensure that utilities important to safety will continue their safety function during emergencies	Design utilities important to safety to continue their safety functions during conditions anticipated during an emergency	Ability of utilities important to safety to continue to perform safety functions during design-basis accidents	O1	Utilities important to safety continue to perform safety functions during design-basis accidents	High	Yes

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 10 of 13)

	Subfunction	Process or activity	Performance measure		Tentative goal	Needed confidence	Site data?
	DESIGN AND PROTECTION OF STRUCTURES, SYSTEMS, AND COMPONENTS IMPORTANT TO SAFETY (FUNCTION 2) (continued)						
P	Ensure that structures, systems, and components important to safety will facilitate inspection, testing, and maintenance	Design structures, systems, and components important to safety to facilitate inspection, testing, and maintenance	Complexity of inspection operations for structures, systems, and components important to safety	P1	Inspection of structures, systems, and components important to safety relatively simple	(a)	No
			Complexity of testing operations for structures, systems, and components important to safety	P2	Testing of structures, systems, and components important to safety relatively simple	(a)	No
			Complexity of maintenance operations for structures, systems, and components important to safety	P3	Maintenance of structures, systems, and components important to safety relatively simple	(a)	No
Q	Provide timely backup power to structures, systems, and components important to safety when needed and during emergencies	Design power systems with backup power capability (diesel generators or other suitable means)	Capacity of backup power supply	Q1	Sufficient capacity to operate all structures, systems, and components important to safety	(a)	No
			Time for backup power supply to become operable	Q2	Response time adequate to serve structures, systems, and components important to safety	(a)	No
R	Provide instrumentation and control systems to monitor and control structures, systems, and components important to safety for all anticipated ranges of operation	Design structures, systems, and components with instrumentation and control systems	Range of operation of monitoring instrumentation	R1	Monitors operable for anticipated ranges of system operation, including design-basis accident conditions	High	Yes
			Range of operation of control instrumentation	R2	Control systems operable for anticipated ranges of system operation, including design-basis accidents	High	Yes

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 11 of 13)

Subfunction	Process or activity	Performance measure		Tentative goal	Needed confidence	Site data?
DESIGN AND PROTECTION OF STRUCTURES, SYSTEMS, AND COMPONENTS IMPORTANT TO SAFETY (FUNCTION 2) (continued)						
R Provide instrumentation and control systems to monitor and control structures, systems, and components important to safety for all anticipated ranges of operation (continued)		Ability to control structures, systems, and components important to safety	R3	Adequate control of essential functions of structures, systems, and components important to safety	High	Yes
CRITICALITY CONTROL (FUNCTION 3)						
S Criticality control	Maintain control of geometry of waste configurations in all phases of waste handling and disposal	Geometry of waste storage arrays	S1	Geometries unfavorable to nuclear criticality	(a)	No
		Geometry of waste package configurations	S2	Geometries unfavorable to nuclear criticality	(a)	No
		Geometry of emplaced waste	S3	Geometries unfavorable to nuclear criticality	(a)	No
		Possibility of accidental disruption of waste geometry leading to unfavorable configurations	S4	Very low probability	High	Yes
	Maintain subcritical assemblies and masses of fissile material in all phases of waste handling and disposal	Mass and fissile content of waste storage arrays	S5	Masses and fissile contents subcritical (see goal S13)	(a)	No
		Mass and fissile content of waste package configurations	S6	Masses and fissile contents subcritical (see goal S13)	(a)	No
		Mass and fissile content of emplaced waste	S7	Masses and fissile contents subcritical (see goal S13)	(a)	No

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 12 of 13)

Subfunction	Process or activity	Performance measure		Tentative goal	Needed confidence	Site data?
CRITICALITY CONTROL (FUNCTION 3) (continued)						
S Criticality control (continued)		Possibility of accidental disruption of waste leading to unfavorable concentrations of fissile materials	S8	Very low probability	High	Yes
	Control the introduction of any neutron moderating materials to waste containing areas	Moderating materials in or around waste storage arrays	S9	No significant moderating materials	(a)	No
		Moderating materials in or around waste package configurations	S10	No significant moderating materials	(a)	No
		Moderating materials in or around emplaced waste	S11	No significant moderating materials	High	Yes
		Possibility of accidental introduction of moderating materials into areas containing waste	S12	Very low probability	High	Yes
	Neutron multiplication	K_{eff} of fissile materials	S13	K_{eff} <0.95 as specified in 10 CFR 60.131(b)(7)	High	Yes
COMPLIANCE WITH MINING REGULATIONS (FUNCTION 4)						
T Comply with mining regulations	Protection of workers who perform assigned safety function	Ability of workers to perform assigned safety functions	T1	Workers perform their assigned safety functions	(a)	No

Table 8.3.2.3-2. Functions, performance measures, and performance goals for Issue 2.7 (repository design criteria for radiological safety) (page 13 of 13)

Subfunction	Process or activity	Performance measure		Tentative goal	Needed confidence	Site data?
		WASTE TREATMENT (FUNCTION 5)				
U Treat waste	Collect secondary site-generated radioactive waste from waste handling areas	Fraction of site-generated waste collected	U1	Site-generated waste collected	(a)	No
	Treat and stabilize or recycle secondary site-generated waste collected	Fraction of site-generated waste treated and stabilized or recycled	U2	Site-generated waste treated and stabilized or recycled	(a)	No
	Package treated and stabilized secondary site-generated waste for disposal offsite	Fraction of treated and stabilized site-generated waste packaged	U3	Treated and stabilized site-generated waste packaged	(a)	No

[a]Needed confidence for nonsite related data will be provided in the plans for repository design.

Table 8.3.2.3-3. Parameters required for Issue 2.7 (repository design criteria for radiological safety) (page 1 of 6)

Related performance goal[a]	Performance or design parameter	Parameter descriptor	Tentative parameter goal	Needed confidence	Expected parameter value	Current confidence	SCP section providing parameter
A1, D2, G2, J1, J9, J10	Dust and particle size distributions	Underground and at site	1 to 10 micron, normal	High	Data not available	Data not available	(c)
A3	Radon emanation rate from tuff	TSw2 unit[b]	(d)	High	0.48 pCi per square meter per second	Low	8.3.1.15, (c)
C2, I2, S13	Bulk density of host rock	TSw2 unit	(d)	High	2.26 to 2.32 g/cc	Medium	8.3.1.15
C2, I2, S11, S13	Elemental composition of host rock	TSw2 unit	Normal composition for tuffs	High	Normal composition for tuffs	Medium	8.3.1.3
C2, I2, S11, S13	Water content of host rock as a function of temperature and time	TSw2 unit	(d)	High	65% saturation	Medium	8.3.1.2
G4	Wind speeds	80 km radius	(d)	High	See Figures 5-3 to 5-7, and Tables 5-6 and 5-7	Medium	8.3.1.12
G4	Wind direction	80 km radius	(d)	High	See Figures 5-3 to 5-7, and Tables 5-6 and 5-7	Medium	8.3.1.12
G4	Atmospheric stability	80 km radius	(d)	Medium	See Table 5-11	Medium	8.3.1.12
G4	Mixing layer depth	80 km radius	(d)	Medium	(e)	Medium	8.3.1.12

Table 8.3.2.3-3. Parameters required for Issue 2.7 (repository design criteria for radiological safety) (page 2 of 6)

Related performance goal[a]	Performance or design parameter	Parameter descriptor	Tentative parameter goal	Needed confidence	Expected parameter value	Current confidence	SCP section providing parameter
G4	Average ambient temperature	80 km radius	(d)	Medium	See Tables 5-2 and 5-3	Medium	8.3.1.12
G4	Atmospheric moisture	80 km radius	(d)	Medium	See Tables 5-2 and 5-5	Medium	8.3.1.12
G4	Precipitation: type, amount, intensity, etc.	80 km radius	(d)	Medium	See Tables 5-2 and 5-4	Medium	8.3.1.12
G4	Barometric pressure	80 km radius	(d)	Medium	See Table 5-2	Medium	8.3.1.12
G4	Size and distance of topographic features from release points	80 km radius	Topographic features beneficial to dispersion	Medium	See U.S. Geological Survey topographic maps	High	Literature
G4	Bioaccumulation of radionuclides in terrestrial flora	80 km radius	(d)	Medium	1×10^{-28} to 1×10^{-14} Ci/kg[f]	Medium	(c)
G4	Bioaccumulation of radionuclides in terrestrial fauna	80 km radius	(d)	Medium	1×10^{-25} to 1×10^{-15} Ci/kg[g]	Medium	(c)
G4	Types of crops raised	80 km radius	(d)	Medium	(h)	Medium	(c)
G4	Amounts of crops raised	80 km radius	(d)	Medium	1×10^{4} to 1×10^{7} kg/yr[i]	Medium	(c)
G4	Types of crops consumed	80 km radius	(d)	Medium	(j)	Medium	(c)

Table 8.3.2.3-3. Parameters required for Issue 2.7 (repository design criteria for radiological safety) (page 3 of 6)

Related performance goal[a]	Performance or design parameter	Parameter descriptor	Tentative parameter goal	Needed confidence	Expected parameter value	Current confidence	SCP section providing parameter
G4	Amounts of crops consumed	80 km radius	(d)	Medium	1×10^4 to 1×10^5 kg/yr	Medium	(c)
G4	Types of animals raised	80 km radius	(d)	Medium	(k)	Medium	(c)
G4	Amounts of animals raised	80 km radius	(d)	Medium	1×10^1 to 1×10^5 kg/yr	Medium	(c)
G4	Types of animals consumed	80 km radius	(d)	Medium	(l)	Medium	(c)
G4	Amounts of animals consumed	80 km radius	(d)	Medium	1×10^4 to 1×10^6 kg/yr	Medium	(c)
G4	Animal consumption of forage	80 km radius	(d)	Medium	1×10^1 to 1×10^4 kg/yr	Medium	(c)
G4	Forage storage time	80 km radius	Goal is values given in Reg. guide 1.109 (NRC, 1977a)	Medium	Data not available	Data not available	(c)
G4	Grazing yield and period	80 km radius	(d)	Medium	75 to 100% of the year	High	(c)
G4	Radius of crop and animal area	80 km radius	(d)	Medium	50 km to bulk of cropland and farms (W to SW)	High	(c)

Table 8.3.2.3-3. Parameters required for Issue 2.7 (repository design criteria for radiological safety) (page 4 of 6)

Related performance goal[a]	Performance or design parameter	Parameter descriptor	Tentative parameter goal	Needed confidence	Expected parameter value	Current confidence	SCP section providing parameter
G4	Volumetric flow of surface water to water bodies	80 km radius	Little or no surface run-off	Medium	Environmental assessment, Section 3.3.1 (DOE, 1986b)	Medium	(c)
G4	Recreational uses of water bodies	80 km radius	Very little recreational use of water	Low	(m)	(m)	(c)
J1	Repository design ventilation pressure drop conditions	Underground	See Section 8.3.2.5	High	See Section 8.3.2.5	See Section 8.3.2.5	8.3.2.5
D5, J9, J10, K1, O1, R1, R2, R3, S4, S8, S12	Frequency and magnitudes of						
	- Tornadoes	At facility	(d)	High	See Section 5.1.1.6[n]	Medium	8.3.1.12
	- Cloud-to-ground lightning strikes	At facility	(d)	Medium	About 18 per year, magnitude unknown	Medium	8.3.1.12
	- Sandstorms/windstorms	At facility	(d)	High	See Table 5-8, and Section 5.1.1.6	Medium	8.3.1.12
	- Snowfall/ice storms	At facility	Rare, low magnitude	High	Rare, low magnitude	Medium	8.3.1.12
	- Repository surface flooding	At facility	PMF[o]	High	PMF[o]	Medium	8.3.1.16

Table 8.3.2.3-3. Parameters required for Issue 2.7 (repository design criteria for radiological safety) (page 5 of 6)

Related performance goal[a]	Performance or design parameter	Parameter descriptor	Tentative parameter goal	Needed confidence	Expected parameter value	Current confidence	SCP section providing parameter
	- Surface and subsurface seismic events	In region	(d)	High	(p)	(p)	8.3.1.17
	- Fault movement within the repository	Surface and subsurface	(d)	High	See Section 1.5.2	Medium	8.3.1.17
D5, J9, J10, K1, O1, R1, R2, R3, S4, S8, S12	- Drift roof fall/ collapse/ failure	Underground	(q)	Medium	Data not available	Data not available	8.3.2.4
	- Landslides	At facility	(q)	Medium	Data not available	Data not available	8.3.1.14
	- Volcanic ash fall	At facility	(q)	Medium	Data not available	Data not available	8.3.1.17
	- Nearby brush fires	Near facilities	(q)	Low	Data not available	Data not available	8.3.1.13
	- Aircraft crashes	At facility	(q)	High	1×10^{-5} to 1×10^{-7} per year	Medium	8.3.1.13
	- Criticality events	In surface and subsurface facilities	Criticality events precluded	High	Not credible	High[r]	8.3.5.5
	- Other potential accidents	Natural or site-related	(s)	High	(s)	(s)	PRAM Program[t]

[a]The letters in this column key the performance parameters to the tentative goals in Table 8.3.2.3-2.
[b]TSw2 unit is the nonlilthophysal Topopah Spring unit (repository horizon).

Table 8.3.2.3-3. Parameters required for Issue 2.7 (repository design criteria for radiological safety) (page 6 of 6)

Footnotes (continued)

[c]Collection of these data are part of the environmental program planned activities and is addressed in the Radiological Monitoring Plan discussed in Section 8.3.1.13 (offsite installations).
[d]Tentative goal is to have further measurements of this parameter verify the range of expected values listed here.
[e]See Quiring (1968).
[f]This range covers all flora for which data is now available, specific values are flora and radionuclide specific.
[g]This range covers all fauna for which data is now available, specific values are fauna and radionuclide specific.
[h]Crops include wheat/grains, corn, apples, potatoes, alfalfa, alfalfa seed, hay, silage, peppers, melons, berries, pecans, leafy vegetables, and honey.
[i]Specific values depend on available crops, crop areas, and crop densities.
[j]Includes all crops listed in footnote h except alfalfa, hay, and silage.
[k]Includes beef cattle, dairy cattle, goats, hogs, sheep, and poultry.
[l]Includes quail, freshwater fish, duck, geese, rabbit, and deer, plus those listed in footnote k.
[m]Very limited use of Crystal Reservoir; swimming pool data not yet available.
[n]Probability at Yucca Mountain is approximately 7.5×10^{-4} in any given year; magnitude is F-0 on Fujita tornado scale (very weak).
[o]PMF = probable maximum flood; the PMF is still under investigation.
[p]Information on seismic events may be found in Section 8.3.1.17.
[q]Parameter goal to be evaluated in terms of frequency and consequence.
[r]Design will preclude criticality accidents per 10 CFR 60.131(b)(7).
[s]Other accident-specific goals to be evaluated as appropriate under preclosure risk assessment methodology (PRAM).
[t]PRAM = preclosure risk assessment methodology.

Specific design products from Issue 4.4 required as input items for this issue are also transmitted from this issue; however, at this time no specific design products or input items other than the repository reference design, operating plan, and supporting analyses have been identified. After design criteria and requests for specific products have been transmitted to Issue 4.4, the repository design is created or updated and placed in the reference information base. The repository reference design, operating plan, and supporting analyses are then available to Issue 2.7 and the performance issues for evaluation.

Test that all goals are met. Once the repository reference design, operating plan, and supporting analyses are ready for evaluation, an assessment will begin of the design against its design objectives. This issue will use the most current site data to perform its assessment of the design; therefore, if site data in the reference information base has been updated since the repository design for the current phase was completed, it is possible that the design of the repository may need to be updated on the basis of the assessment under Issue 2.7. Issues 2.1, 2.2, and 2.3 will perform performance assessments of the repository design against applicable performance criteria after the design evaluation.

The design evaluation consists of a comparison of the design with the design criteria and objectives. If any objectives are not satisfied, both the design and the unsatisfied objectives will be examined to develop the appropriate solution. The solution may involve (1) changing the design of the repository or (2) changing a radiation safety design objective that has been shown to be unreasonable or unattainable. Necessary and reasonable objectives will not be altered. If the design cannot be corrected to meet necessary and reasonable objectives, then an unfavorable resolution of this issue has occurred. If the design can be corrected, then the corrected design is reassessed against the design objectives.

Part of the design assessment is an evaluation of whether the ALARA principle has been satisfied. This will require cost-benefit analyses and tradeoff studies. Most of these studies will have been performed before taking the design into the advanced conceptual design phase; however, it may prove necessary to perform more of these analyses if new alternatives are developed after the design is substantially complete.

Upon satisfactory completion of the design assessment by this issue (i.e., all design objectives have been met and the ALARA principle has been adequately addressed), the final question to be asked is: Is the design sufficient for license application? If the answer to this question is no, then another iteration of the design process is performed and the design is improved and more details are developed. If the answer to the question is yes, then a favorable resolution of Issue 2.7 has been achieved.

Interrelationships of information needs

The question asked by this issue addresses the design criteria listed in 10 CFR 60.131 through 60.133. These design criteria cover a wide range of topics; however, this issue is only concerned with those design criteria that have radiological protection as their basis. In the preceding discussion, those design criteria that have radiological protection as their basis were

grouped into five functions. Those five functions form the basis for the following information needs:

Information need	Subject
2.7.1	Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to radiological protection have been met.
2.7.2	Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to the design and protection of structures, systems, and components important to safety have been met.
2.7.3	Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to criticality control have been met.
2.7.4	Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to compliance with mining regulations have been met. (This issue does not require site data and so is not discussed in the SCP).
2.7.5	Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to waste treatment have been met. (This issue does not require site data and so is not discussed in the SCP).

Information Need 2.7.1 calls for a determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to radiological protection have been met. This might be misleading because all the criteria (performance goals) under this issue pertain to radiological protection in one way or another. In this instance, those criteria pertaining to radiological protection are those that arise in the performance allocation for this issue under the function "radiological protection." These are shown in Table 8.3.2.3-2. This information need will evaluate the reference repository design, operating plan, and supporting analyses to assess compliance with these design criteria and objectives.

Information Need 2.7.2 calls for a determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to the design and protection of structures, systems, and components important to safety have been met. The additional design objectives (performance goals) for this information need are in Table 8.3.2.3-2 under the function "design and protection of structures, systems, and components important to safety." The evaluation will involve the analysis of design-basis accidents and other less severe accidents that might affect structures, systems, and components important to safety. Many of

these analyses will have been performed as part of the design process; these will be available for use in the Issue 2.7 evaluation.

Information Need 2.7.3 calls for a determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to criticality control have been met. The additional design objectives (performance goals) for this information need are in Table 8.3.2.3-2 under the function "criticality control." Evaluation of these design criteria and design objectives will entail the assessment of operating plans as well as repository equipment. When suggesting corrections to any problems that may be discovered, major emphasis will be placed on using simple design features rather than operating procedures to control criticality.

Information Need 2.7.4 calls for a determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to the required compliance with mining regulations have been met. The additional design objectives (performance goals) for this information need are in Table 8.3.2.3-2 under the function "compliance with mining regulations." Compliance with the mining regulations is required for those design criteria in 30 CFR Chapter I, Subchapters D, E, and N relevant to the design of structures, systems, and components important to safety. This information need will evaluate the reference repository design, operating plan, and supporting analyses to assess compliance with those design criteria in 30 CFR that are relevant to this issue.

Information Need 2.7.5 calls for a determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to the waste treatment have been met. The additional design objectives for this information need are in Table 8.3.2.3-2 under the function "waste treatment." The only regulatory design objective for waste treatment in 10 CFR Part 60 is for site-generated waste to be treated and packaged in a form suitable for onsite or offsite disposal. The current design basis is for offsite disposal. All additional design objectives (performance goals) are based on this choice. This information need will evaluate the reference repository design, operating plan, and supporting analyses to assess compliance with those design criteria and objectives.

These evaluations performed under Information Needs 2.7.1 through 2.7.5 will be performed in conjunction with each other. No single information need performs the final resolution of this issue. The final product of all the above information needs is a report that addresses each of the design criteria and design objectives and discusses the compliance or noncompliance of the repository design. This report will constitute the resolution of Issue 2.7 in the final design stages.

To answer the information needs, both design and site information is needed; however, only three of the information needs require site data: Information Needs 2.7.1, 2.7.2, and 2.7.3. Information Need 2.7.1 requires site data to evaluate the design against design criteria and performance goals dealing with concentrations of radon and daughter products, use of host rock properties in providing shielding, and releases of radioactive materials to the environment. Information Need 2.7.2 requires site data to evaluate the design of structures, systems, and components important to safety with respect to protection from site-related accidents. Finally, to evaluate

criticality control, Information Need 2.7.3 requires the same site data as Information Need 2.7.2. In the following sections discussing the information needs (i.e., Information Needs 2.7.1 in Section 8.3.2.3.1, and 2.7.2 and 2.7.3 in Section 8.3.2.3.2), only those information needs that require site data are addressed, and only those aspects of the information needs concerning site data are discussed.

The schedule information for Issue 2.7 (repository design criteria for radiological safety) is presented in Section 8.3.2.3.3.

8.3.2.3.1 Information Need 2.7.1: Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to radiological protection have been met

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

Chapter 3 contains discussions about the present state of the knowledge on the site hydrology, including uses of surface water and ground water. Section 4.1.2.6 (background radioactivity of repository ground water) discusses what is known about the radionuclide content of repository ground water to date. Chapter 5 contains discussions about the present state of knowledge on the meteorology of the site and surrounding region. Background radiation levels are discussed in Section 3.4.7 of the environmental assessment (DOE, 1986b). Further discussions on the subject of radiological protection of the public and the workers may be found in Sections 6.1.1.4.1 (radiological protection design requirements), 6.4.4 (Issue 2.1: public radiological exposures--normal conditions), 6.4.5 (Issue 2.2: worker radiological safety--normal conditions), 6.4.6 (Issue 2.3: accidental radiological releases), and 6.4.7 (Issue 2.7: repository design radiological criteria for safety. Section 8.3.5.1 contains discussions of the preclosure risk assessment methodology (PRAM) program. The PRAM program includes radiological risk to the workers during normal operations as part of its scope. Sections 2.5 (radiological protection), 6.1 (radioactive releases during normal operations), and 6.2 (releases under abnormal conditions) of the Site Characterization Plan Conceptual Design Report (SCP-CDR) (SNL, 1987) also contain discussions relevant to this issue.

Parameters

As can be seen in Table 8.3.2.3-2, this information need requires mostly design information; therefore, the discussions here related to site data will be brief. The site parameters required by this information need are those needed to (1) determine concentrations of naturally occurring radon and short-lived daughters in the repository airstreams, (2) make use of the shielding properties of the host rock, and (3) quantify the transport of radioactive materials to the workers and to the public. The site data required by this information need along with the SCP section providing the information are listed in the following table.

Data requirement	SCP section
REPOSITORY ROCK AND GROUND-WATER DATA	
Radon emanation rate from the tuff	8.3.1.15.1
Elemental composition of the host rock	8.3.1.3.2
Bulk density of the host rock	8.3.1.15.1
Water content and saturation of the host rock as a function of temperature and time	8.3.1.2.3
METEOROLOGICAL DATA	
Wind speeds in the region	8.3.1.12.2
Prevalent wind directions	8.3.1.12.2
Atmospheric stability of the area	8.3.1.12.2
Atmospheric mixing layer depth of the area	8.3.1.12.2
Average ambient temperature of the area	8.3.1.12.2
Atmospheric moisture of the area	8.3.1.12.2
Area precipitation, including type, amount, intensity, etc.	8.3.1.12.2
Dust and particle size distributions underground and on the site	(a)
Size and distance of major topographic features from release points	8.3.1.14.1
AGRICULTURAL AND CULTURAL DATA	
Bioaccumulation of radionuclides in the terrestrial flora	(a)
Bioaccumulation of radionuclides in the terrestrial fauna	(a)
Types and amounts of crops raised	(a)
Types and amounts of crops consumed	(a)
Types and amounts of animals raised	(a)

Data requirement	SCP section
AGRICULTURAL AND CULTURAL DATA (CONTINUED)	
Types and amounts of animals consumed	(a)
Animal consumption of forage	(a)
Forage storage time	(a)
Grazing yield and period	(a)
Radius of the crop and animal area	(a)
Volumetric flow of surface water to water bodies	(a)
Recreational uses of area water bodies	(a)

[a]Collection of these data is part of the environmental program planned activities and is addressed in the Radiological Monitoring Plan, which is discussed in Section 8.3.1.13.

Logic

Among the design objectives developed for this issue is a performance goal limiting the concentration of naturally occurring radon, a performance goal for the shielding properties of the host rock, and a performance goal limiting releases of radioactive materials based on eventual exposure of the workers and public. Site data that characterizes the radon source term is needed both for the creation of the design and for the evaluation of the effectiveness of the design in limiting the radon concentration. This data is listed in the previous table. To evaluate the shielding properties of the host rock, site data is needed that will allow the computation of neutron and gamma cross sections. Data of this type are composition, density, and saturation data and are also listed in the previous table. These data should reflect the rock properties before, during, and after emplacement. To evaluate the effectiveness of the repository in limiting releases of radioactive materials to acceptable levels, data are needed that will characterize the transport of any released radionuclides in the environment. These data include information on the short- and long-term pathways. In this instance, the short-term pathways are dominated by atmospheric transport. The meteorological data needed to characterize the atmospheric transport of radionuclides are listed in the table above. Long-term pathways include ingestion of radionuclides deposited on plants, contained in drinking and recreation waters, and deposited in animals that are consumed. Again, the data needed to assess these pathways are listed above.

The only activities under this issue are evaluations of the design at each design phase. This is actually supporting design by providing feedback to the designers to be used in the next phase of design or in modifying the current design. Section 8.3.2.5 (preclosure design and technical feasibility) contains a complete listing of design activities, including those to be performed in support of radiological safety.

8.3.2.3.1.1 Design Activity 2.7.1.1: Design evaluation for compliance with radiological safety design criteria and performance goals

Objectives

The objective of this activity is to evaluate the repository design against the radiological safety design criteria and performance goals at each phase of the design and provide feedback to the designers on needed corrections or modifications.

Parameters

The site parameters needed to perform this activity are all those listed in the technical basis section for this information need.

Description

This activity will consist of a complete radiological safety design analysis and performance goal assessment of the reference repository design, operating plan, and supporting analyses at each phase of design. Much of the analysis for this evaluation will be performed as part of the design process and will be supplied for review as part of the supporting analyses. Other analyses required for this evaluation will be performed in parallel with performance assessment analyses required by Issues 2.1, 2.2, and 2.3 (Sections 8.3.5.3 through 8.3.5.5). These issues will supply their results to Issue 2.7 for a determination that design criteria and performance goals have been met.

8.3.2.3.1.2 Application of results

The information generated by this information need will be used directly by Issue 4.4 (preclosure design and technical feasibility, Section 8.3.2.5) to demonstrate compliance with all radiological safety design criteria and performance goals. The end use of the evaluations performed by this information need is to resolve Issue 2.7 and to be included in the safety analysis report as part of the license application.

8.3.2.3.2 Information Needs 2.7.2 and 2.7.3: (1) Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to the design and protection of structures, systems, and components important to safety have been met, and (2) Determination that the design criteria in 10 CFR 60.131 through 60.133 and any appropriate additional design objectives pertaining to criticality control have been met

Technical basis for addressing the information need

Link to the technical data chapters and other support documents

The only site data that these two information needs require are data that characterize site-related accidents. This information is needed to assess the performance of structures, systems, and components important to safety. Most of this information is related to meteorology or seismic concerns. Chapter 5 contains discussions about the present state of the knowledge on the meteorology of the site and surrounding region. Discussions of the site seismology are contained in Section 8.3.1.17. Further discussions of the subject of radiological protection of the public and workers may be found in Section 6.1.1.4.1 (radiological protection design requirements), 6.4.4 (Issue 2.1: public radiological exposures--normal conditions), 6.4.5 (Issue 2.2: worker radiological safety--normal conditions), 6.4.6 (Issue 2.3: accidental radiological releases), and 6.4.7 (Issue 2.7: repository designation for radiological safety). Section 8.3.5.1 contains discussions on the preclosure risk assessment methodology (PRAM) program. Sections 2.5 (radiological protection), 6.1 (radiological releases during normal operations), and 6.2 (releases under abnormal conditions) of the Site Characterization Plan-Conceptual Design Report (SCP-CDR) (SNL, 1987) also contain discussions relevant to this information need. Finally, two appendices of the SCP-CDR have information especially relevant to this information need. These are Appendix F (preclosure radiological safety analysis), which is a preliminary analysis of accidents at the Yucca Mountain repository prepared to support the development of the preliminary Yucca Mountain Project Q-list, and Appendix L (items important to safety and retrievability), which contains a discussion of the method used and results of the preliminary Q-list.

Parameters

As can be seen in Table 8.3.2.3-2, this information need requires mostly design information. The site parameters required by this information need are those required to determine the characteristics and frequencies of site-related accidents. Below is a list of site data required by this information need along with the SCP section providing the information.

Data requirement	SCP section
Frequency and characteristics of	
Tornadoes	8.3.1.12.4
Cloud-to-ground lightning strikes	8.3.1.12.4
Sandstorms	8.3.1.12.4
Snow fall	8.3.1.12.4
Ice storms	8.3.1.12.4
Repository surface flooding	8.3.1.16.1, 8.3.1.16.3
Repository flooding from ground-water inflow	8.3.1.16.1, 8.3.1.16.3
Surface and subsurface seismic events	8.3.1.17.3
Fault movement within the repository	8.3.1.17.2
Drift roof fall, collapse, or failure	8.3.2.4.1
Surface landslides	8.3.1.14.1
Volcanic ash fall	8.3.1.17.1
Nearby forest or brush fires	8.3.1.13.1
Aircraft and helicopter crashes in the area of the surface facilities	8.3.1.13.1
Other potential accidents	Preclosure risk assessment methodology (PRAM) program 8.3.1.13.2

Logic

Both of the information needs included in this section involve the protection of structures, systems, and components important to safety. Information Need 2.7.2 addresses the design of such items, and Information Need 2.7.3 addresses compliance with mining regulations concerning such

items. The only site data needed to design structures, systems, and components important to safety or to assess the design of these items are data concerning site-related accidents against which these items are to be protected. These are listed in the previous parameters subsection.

There are no specific activities planned under these information needs; however, there are activities planned for the issue as a whole. These activities are discussed in the logic section for Information Need 2.7.1 (Section 8.3.2.3.1).

8.3.2.3.2.1 Application of results

The information generated by this information need will be used directly by Issue 4.4 (Section 8.3.2.5) to demonstrate compliance with all radiological safety design criteria and performance goals. The end use of the evaluations performed by this information need is to resolve this issue (2.7) and to be included in the safety analysis report, which is a part of the license application.

8.3.2.3.3 Schedule for repository design criteria for radiological safety

Issue 2.7 (repository design criteria for radiological safety) includes three information needs. There are no specific site-related activities planned under Information Needs 2.7.2 and 2.7.3. However, there are activities planned for Issue 2.7 as a whole. Information Need 2.7.1 contains one design activity. The schedule information for this design activity is summarized in Figure 8.3.2.3-3. This figure includes the design activity number and a brief description, as well as major events associated with the activity. A major event, for purposes of this schedule, may represent the initiation or completion of an activity, completion or submittal of a report to the DOE, an important data feed, or a decision point. Solid lines on the schedule represent activity durations and dashed lines show data transferred into or out of this design issue. The events shown the schedule and their planned dates of completion are provided in Table 8.3.2.3-4.

This activity-level schedule, in combination with information provided in the logic diagram for this issue (Figure 8.3.2.3-2), is intended to provide the reader with a basic understanding of the relationships between major elements of the site, performance, and design programs. The information provided in Table 8.3.2.3-4 and Figure 8.3.2.3-3, however, should be viewed as a snapshot in time.

The overall program schedule presented here is consistent with the Draft Mission Plan Amendment (DOE, 1988a). The site characterization program will undergo a series of refinements following issuance of the statutory SCP. Refinements will consider factors both internal and external to the site characterization program, such as changes to the quality assurance program. Such refinements are to be considered in ongoing planning efforts, and

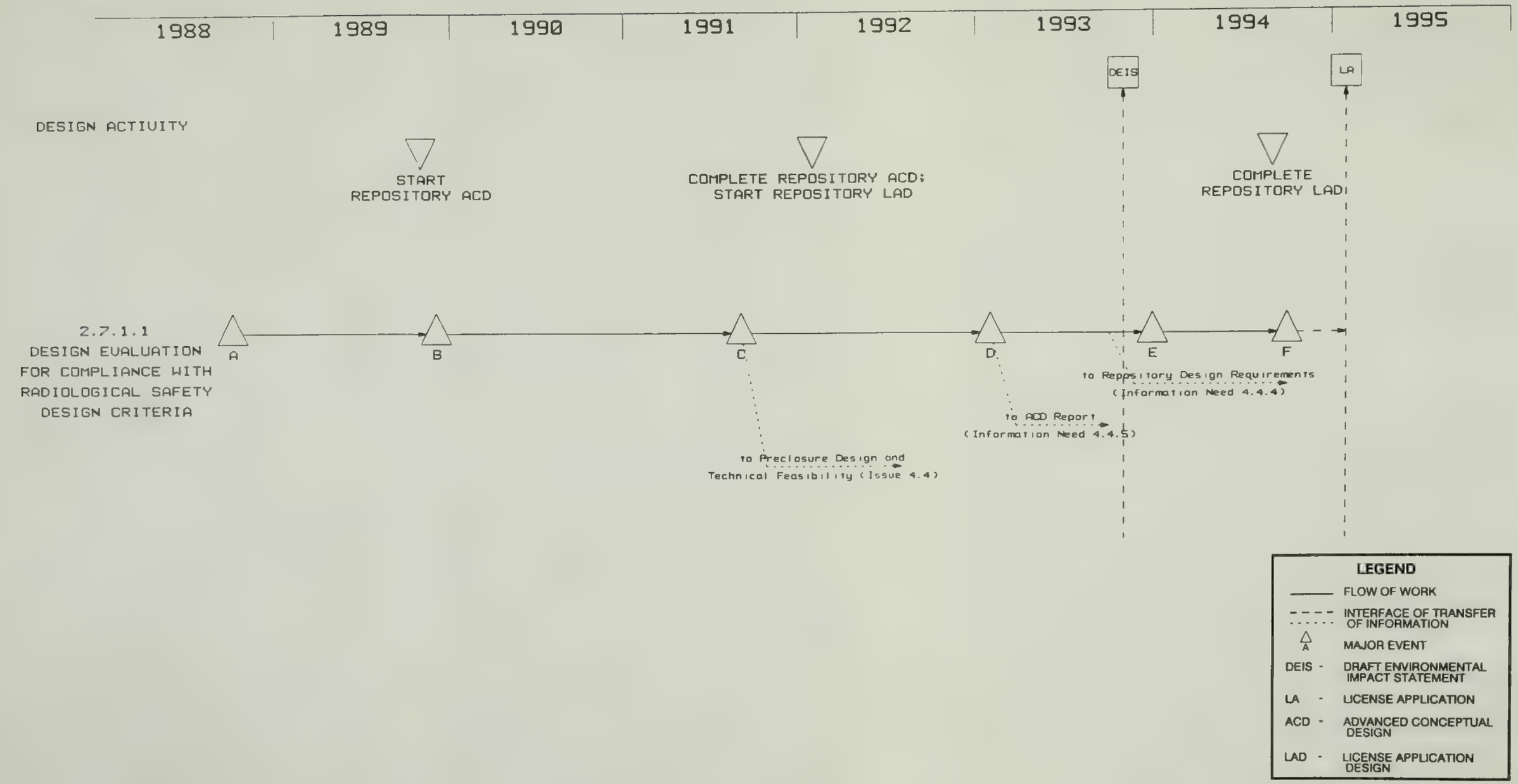


Figure 8.3.2.3-3. Schedule information for activities in Issue 2.7 (repository design criteria for radiological safety). See Table 8.3.2.3.4 for description of major events. This network is consistent with the Draft Mission Plan Amendment (DOE, 1988a) schedule. Revisions will be published in semiannual site characterization progress reports as new information becomes available.

Table 8.3.2.3-4. Major events and planned completion dates for activities in Issue 2.7 (repository design criteria for radiological safety)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
2.7.1.1	Design evaluation for compliance with radiological safety design criteria	A	Continue generation of radiological safety requirements	10/88
		B	Radiological requirements identified feed to advanced conceptual design (ACD) repository design requirements; Continue to generate radiological requirements	11/89
		C	Initiate preclosure risk assessment methodology (PRAM) analysis of ACD	12/90
		D	Draft report available to the U.S. Department of Energy (DOE) on the results of PRAM analysis of ACD	1/93
		E	Start preparation of report on PRAM analysis of license application design (LAD)	12/93
		F	Draft report available to DOE on the results of PRAM analysis of LAD	7/94

[a]The letters in this column key major events shown in Figure 8.3.2.3-3.

changes that are implemented will be reflected in the semiannual progress reports. Summary schedule information for this and other repository design issues can be found in Sections 8.5.3 and 8.5.6.

Nuclear Waste Policy Act
(Section 113)

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.2.4, Nonradiological Health and Safety

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.2.4 Issue resolution strategy for Issue 4.2: Are the repository design and operating procedures developed to ensure nonradiological health and safety of workers adequately established for the resolution of the performance issues?

Regulatory basis for the issue

In addition to the radiological safety requirements for workers, the NRC also specifies that DOE should comply with mining regulations (10 CFR 60.131(b)(9)). The NRC points out that the design of the geologic repository operations area should include provisions for worker protection adequate to ensure that structures, systems, and components important to safety can perform their intended functions.

Resolution of this issue requires that designs and operating procedures that ensure worker nonradiological health and safety during the preclosure period be selected and implemented. Certain aspects of the designs must also be demonstrated to verify that the design approach produces designs that are safe. Design aspects that must be demonstrated are related to the designs of the underground system elements located within the underground areas heated by the emplaced waste; this heating presents a unique design environment. The overall design process is described in Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5). The relationship of Issue 4.2 to Issue 4.4 is graphically described in Figure 8.3.2.1-1 of Section 8.3.2.1. The role of this issue is to define these aspects of the overall design that impact worker health and safety, to prescribe design requirements necessary to meet the regulatory requirements and to transmit the design requirements to Issue 4.4 for incorporation into the overall design. When each phase of the design process, advanced conceptual design, license application design, etc., is completed, the design package developed under Issue 4.4 is reviewed by this issue to evaluate whether all of its goals are met. The logic of this process, from the viewpoint of Issue 4.2 is depicted in the diagram of Figure 8.3.2.4-1.

The goal of Issue 4.4 is to ensure that the design, construction, and operation of the repository can be accomplished with reasonably available technology. The implication of Issue 4.4 is that the repository will be able to draw upon an existing experience base in the design and the development of procedures for ensuring worker nonradiological health and safety. To this end, this issue will draw upon regulatory requirements to establish goals for the design and operation to ensure worker health and safety. These goals will be imposed on Issue 4.4 in the form of requirements and constraints on the overall design and operating procedures. In the SCP, the goals are generally restricted to those that may require data from site characterization.

From the standpoint of worker nonradiological health and safety, the designs and procedures for the repository must consider at least the following factors:

1. The ability to identify unacceptable or marginal areas of ground.

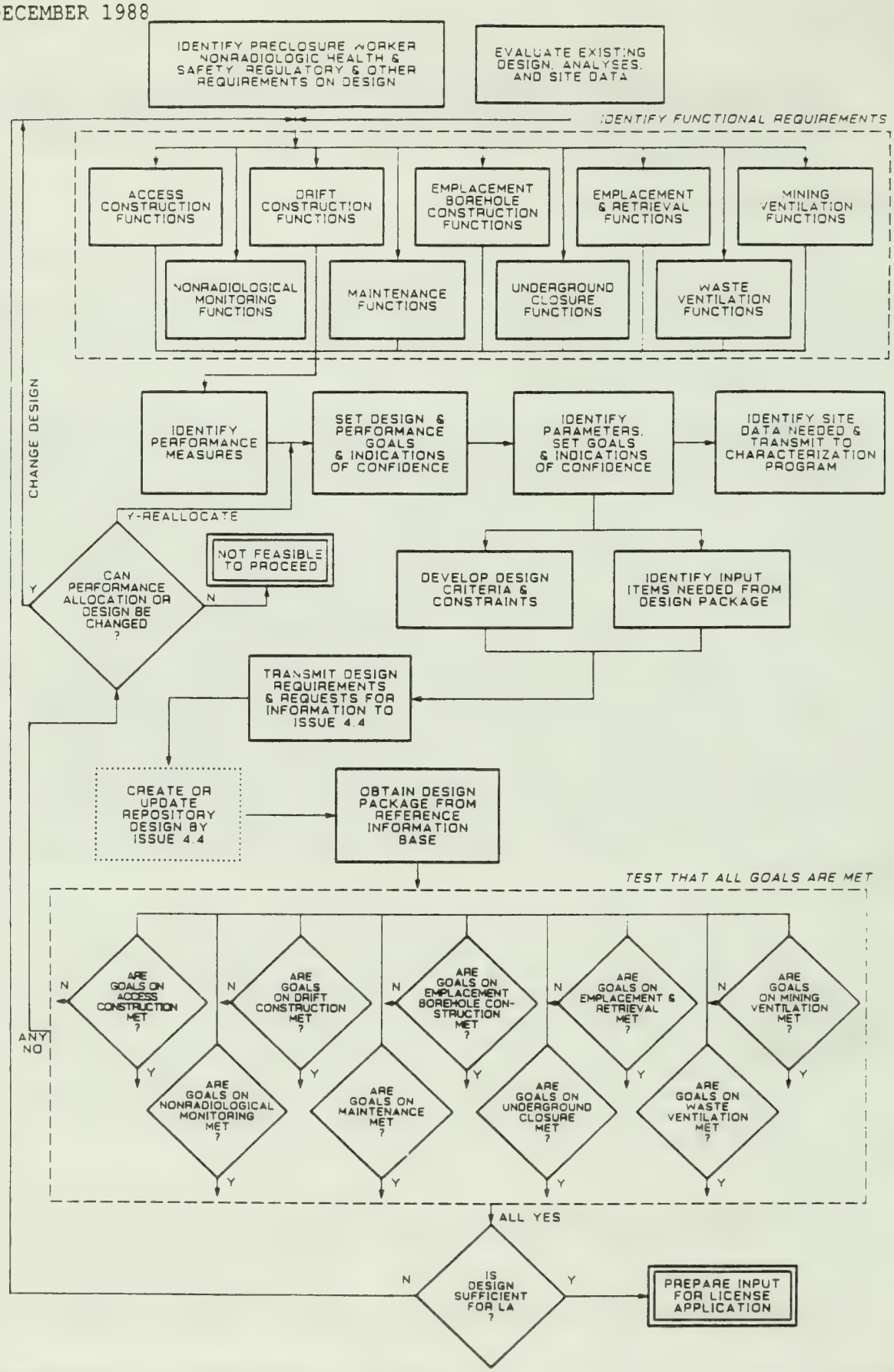
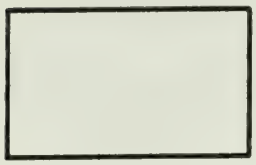
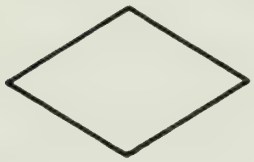


Figure 8.3.2.4-1a. Logic diagram for Issue 4.2 (nonradiological health and safety). See Figure 8.3.2.4-1b for legend. Section 8.3.2.1 describes the relationships and interfaces between design and performance issues.

LEGEND



ACTIVITY PERFORMED TO RESOLVE ISSUE



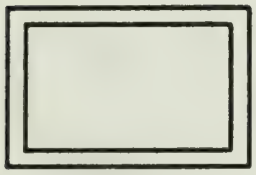
TEST TO DETERMINE SUBSEQUENT ACTIVITY



ACTIVITY PERFORMED BY INDICATED ISSUE



ACTIVITY WITH MULTIPLE SIMILAR ACTIVITIES OR TESTS



DECISION ABOUT ISSUE RESOLUTION

Y - YES N - NO LA - LICENSE APPLICATION

Figure 8.3.2.4-1b. Legend for Figure 8.3.2.4-1a.

2. The ability of the repository construction to adapt to constraints imposed by rock characteristics (Section 8.3.1.15).

3. Use of reasonably available technology (Issue 4.4, Section 8.3.2.5).

4. Maintenance of underground openings during repository operation and closure (Issue 2.4, Section 8.3.5.2).

5. The development of rigorous maintenance procedures and schedules for all repository facilities and operating equipment.

6. Phenomena such as thermally induced fracturing, hydration, or dehydration.

7. Stratigraphic or structural features that could compromise worker safety.

8. Potential for roof falls (drift and access stability during construction and repository operation).

9. Rock support requirements.

10. Air quality (potential for natural gases such as radon or methane, high concentrations of equipment exhaust gases, and harmful dusts).

11. Working temperature.

12. Potential for equipment-related accidents. (This is not a site-related factor unless site conditions restrict the size of openings or corner radii.)

The major factors that impact worker safety are associated with the underground facilities. These factors are opening stability and ventilation. At the Yucca Mountain site, ground-water inflow sufficient to cause a worker safety problem is not anticipated (Section 8.3.1.16). The natural rock temperature at Yucca Mountain does not present a concern, but the rock temperatures and hence the worker environment during retrieval could be of concern. Equipment-related accidents are not expected to be caused by restrictive site conditions. Accesses and drifts will be sized to allow adequate room for maneuvering of equipment without endangering personnel. Rock stability requires that the characteristics of the rock be known and that a design procedure is established to accommodate conditions expected in construction, waste emplacement, and waste retrieval.

Approach to resolving the issue

The approach used to resolve this issue is graphically depicted in Figure 8.3.2.4-1 and is briefly described by the following steps:

1. The "system elements" pertinent to the issue are identified; only the preclosure system elements as presented in DOE (1986c) are considered since workers are present only during the preclosure period of the repository. Additionally, it is judged that worker nonradiological health and safety is imperiled only by operational

or construction activities. Applying this criteria eliminates the waste emplacement package and the site elements. The remaining element is the repository. The subelements under the repository element that are considered are mining, waste handling, decommissioning, and support. The elements under each repository subelement are evaluated individually to determine if (1) they are pertinent to the nonradiological health and safety of the repository workers and (2) they will require site data for analysis.

For the purpose of resolving this issue, the activities presented in SNL (1987, Appendix P) are replaced by the physical facilities in which the activities are performed, (e.g., access construction (System Element 1.2.1.1) is considered to be the "accesses" to the underground facilities of the repository).

Note: Those system elements not requiring site data for design and assessment of nonradiological health and safety will not be considered beyond the system element identification step. These elements will be addressed in the plans for repository design.

2. The functions that are performed within the system elements identified as pertinent to worker nonradiological health and safety are specified. The functions are selected using the following criteria: (1) is there a potential for failure of the structure in which the function is performed and (2) is there a potential for failure of the equipment used to perform the function? An example function is "ventilation supply and exhaust" for System Element 1.2.1.1 (access construction).

3. The processes or activities accomplished within the system elements selected are listed in conjunction with the functions. The listing is not all inclusive, but it does note those significant processes that can impact worker nonradiological health and safety.

4. The required performance (performance measure) of the system element in accomplishing its functions is specified. Under System Element 1.2.1.1, access construction, an example of a performance measure is "usable access over 100 years."

5. The final step of the issue resolution strategy specifies the tentative performance goals and needed confidence. Performance goals are a statement of what the system element must do or provide to ensure worker safety. Needed confidence is a measure of the importance assigned to achieving the goal set for the system element. An example of a performance goal and confidence assignment from System Element 1.2.1.1, access construction, for the function of ventilation supply and exhaust is a goal of at least 60 ft/min for air velocity during construction; this goal has been established by industry as adequate to ensure a safe working environment. This minimum air flow velocity is set to ensure good mixing and sweeping to avoid stagnant air pockets. A needed confidence assignment of "high" implies that the ability to supply adequate air to the underground is essential for worker health and safety.

Reasonable assurance that the repository design and operating procedures will ensure worker nonradiological health and safety (i.e., the resolution of this issue) will result from the following:

1. Assignment and implementation of appropriate design safety factors.

2. Establishment of design criteria that mandate compliance with regulations governing health and safety requirements.

3. Evaluation of design to assure compliance with the required regulations.

4. Establishment of training and safety programs.

The types of design analyses that will be used to design the system elements identified are specified in Information Need 4.2.1 (Section 8.3.2.4.1). Implementation of these analyses requires both site and nonsite information (data). The types of site information required are specified in Information Need 4.2.1. Detailed descriptions of the site information required are provided in Section 8.3.2.5, Tables 8.3.2.5-1 through 8.3.2.5-12.

The Yucca Mountain mined geologic disposal system elements and subelements that have an impact on the nonradiological health and safety of the work force and visitors include System Elements 1.2.1 (mining), 1.2.2 (waste handling), 1.2.4 (decommissioning), and 1.2.5 (support). The system subelements that require site-specific data for design and the development of operational procedures to ensure worker nonradiological health and safety are the following:

System subelement	Subject
1.2.1.1	Access construction
1.2.1.2	Drift construction
1.2.1.3	Borehole construction
1.2.1.6	Mining ventilation
1.2.2.5	Retrieval
1.2.2.7	Waste ventilation
1.2.4.1	Underground closure
1.2.5.6	Maintenance
1.2.5.9.2	Nonradiological monitoring

Those subelements of the Yucca Mountain mined geologic disposal system that affect worker nonradiological health and safety but do not require site data for analysis or design are the following:

System subelement	Subject
1.2.1.4	Rock handling
1.2.2.1	Receiving
1.2.2.2	Preparation
1.2.2.3	Storage
1.2.2.4	Emplacement
1.2.2.6	Shipping
1.2.4.2	Surface facility decommissioning
1.2.5.2	Administration

Note that construction and inspection are included under the System Element 1.2.1.3, borehole construction, and, therefore, are not included under System Element 1.2.2.4, emplacement. Thus, no site data are needed for emplacement.

The functions, processes performed, performance measures, performance goals, and needed confidence for achieving the stated performance goals for each system element identified as pertinent to Issue 4.2 are given in Tables 8.3.2.4-1 through 8.3.2.4-9. Those elements selected that do not require site data as input to determine that worker health and safety are achieved are not included.

Interrelationships of information needs

The information needs subsidiary to this issue are as follows:

Information need	Subject
4.2.1	Site and performance information needed for design (Section 8.3.2.4.1)
4.2.2	Potential nonradiological hazards to personnel (not addressed in the SCP)
4.2.3	Design measures for avoiding or mitigating hazards to personnel (not addressed in the SCP)

Table 8.3.2.4-1. Performance measures, goals, and needed confidences for System Element 1.2.1.1 (access construction) pertinent to Issue 4.2, nonradiological health and safety (page 1 of 4)

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Underground facility access and egress	Safe access to underground facilities (usable access for 100 yr)	Limit rock damage	
		- Overbreak <6 in. average	Medium
		- Blast-induced fracture extent into intact rock <3 m average	Medium
	Access closure (combined performance of rock and opening support)	Access closure	
		- Closure rate <1 mm/yr in shafts and ramps	Medium
		- Total closure in ramps <6 in. in 100 yr	Medium
		- Total closure in shafts <3 in. in 100 yr	Medium
		Rockfall	
		- <5 ton average/1,000 ft/yr (ramps)	Medium
		- Maximum rock or slab size <2 tons	Medium
		- Rockfall in ramps contained by support system	Medium
		- Rockfall or average liner spall <1/2 ton/1,000 ft/yr (shafts)	Medium

Table 8.3.2.4-1. Performance measures, goals, and needed confidences for System Element 1.2.1.1 (access construction) pertinent to Issue 4.2, nonradiological health and safety (page 2 of 4)

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Underground facility access and egress (continued)		- All rockfall or liner spall to be retained (by supplemental support or liner system) (shafts)	Medium
	Acceptable maintenance frequencies	Maintenance	
		- Inspection and minor maintenance will be done on a continuing basis	Medium
		- Major maintenance frequency >25 yr	Medium
	Access sizes and grades compatible with requirements for personnel, material transport, and utility routing	Grades	
		- Waste ramp grade <10%	High
		- Tuff ramp grade <20%	High
		Size	
		- Men and materials shaft 20 ft minimum diameter	Medium
		- Waste transport ramp roadway width 5 ft greater than waste transporter (minimum clearance between and ramp or ramp equipment equipment >2 ft)	Medium

Table 8.3.2.4-1. Performance measures, goals, and needed confidences for System Element 1.2.1.1 (access construction) pertinent to Issue 4.2, nonradiological health and safety (page 3 of 4)

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Underground facility access and egress (continued)		- Tuff ramp diameter adequate for tuff conveyor movement of major construction equipment and utilities (20 ft)	Medium
Removal of broken rock	Compliance with 30 CFR Part 57	Adequate clearance for rock removal equipment	Medium
		Safety systems (conveyors)	High
		- Barriers and guards	
		- Heat sensors	
		- Slack sensors	
		- Back run preventers	
		Dust suppression	High
Ventilation supply and exhaust	Pressure drops in accesses	Accesses sized to limit air velocities and to accommodate future changes in air demands	
		- <3,000 ft/min in shafts	Medium
		- <1,500 ft/min in ramps	Medium
		- >60 ft/min in all accesses	Medium

Table 8.3.2.4-1. Performance measures, goals, and needed confidences for System Element 1.2.1.1 (access construction) pertinent to Issue 4.2, nonradiological health and safety (page 4 of 4)

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Emergency egress	Compliance with 30 CFR Part 57	Accesses designed to provide safe egress during emergencies	High

[a]These goals are integrated with goals from other issues in the discussion of Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5, Tables 8.3.2.5-1 through 12). Site characterization-related design or performance parameters, their goals, and confidences are also established in these tables.

Table 8.3.2.4-2. Performance measures, goals, and needed confidences for System Element 1.2.1.2 (drift construction) pertinent to Issue 4.2, nonradiological health and safety (page 1 of 3)

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Underground facility access	Safe and usable access for 100 yr	Limit rock damage	
		- Overbreak <6 in. average	Medium
		- Blast induced fracture extent into intact rock <3 m average	Medium
	Drift closure (combined performance of rock and opening support system)	Drift closure	Medium
		- Rate of closure <1 mm/yr in main and access drifts	Medium
		- Rate of closure <3 mm/yr in waste emplacement drifts	Medium
		- Total closure <6 in. in 100 yr	Medium
	Rockfall quantity and retention	Rockfall retention	Medium
		- <5 ton/1,000 ft/yr	
		- Maximum rock or slab size <2 tons	
		- Rockfall retained by support system	Medium
	Acceptable maintenance frequencies	Maintenance	
		- Inspection and minor maintenance will be performed on a continuing basis	Medium

Table 8.3.2.4-2. Performance measures, goals, and needed confidences for System Element 1.2.1.2 (drift construction) pertinent to Issue 4.2, nonradiological health and safety (page 2 of 3)

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Underground facility access (continued)		- Major maintenance frequencies >25 yr	Medium
	Drift size and grades for personnel and material transport and utility routing	Drift size 6 ft wider than equipment size	High
		Drift grades <8%	High
Removal of broken rock	Compliance with 30 CFR Part 57	Adequate clearance	High
		Safety systems (conveyors)	High
		- Barriers and guards	
		- Heat sensors	
		- Slack sensors	
		Dust control and suppression	High
Ventilation supply and exhaust	Pressure drop in drifts	Drifts adequately sized to limit air velocities and to cover changes in future air needs	
		- Velocities in supply mains 2,000 ft/min	Medium
		- Velocities in returns <2,000 ft/min	Medium
		- >60 ft/min in all occupied drifts	High

Table 8.3.2.4-2. Performance measures, goals, and needed confidences for System Element 1.2.1.2 (drift construction) pertinent to Issue 4.2, nonradiological health and safety (page 3 of 3)

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Emergency egress	Compliance with 30 CFR Part 57	Ventilated emergency escapeways	High

[a]These goals are integrated with goals from other issues in the discussion of Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5, Tables 8.3.2.5-1 through 12). Site characterization-related design or performance parameters, their goals, and confidences are also established in these tables.

Table 8.3.2.4-3. Performance measures, goals, and needed confidences for System Element 1.2.1.3 (borehole construction) pertinent to Issue 4.2, nonradiological health and safety

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Construct borehole	Compliance with 30 CFR Part 57 and ACGIH[b] (1986)	Air quality requirements same as specified for System Element 1.2.1.6 (mining ventilation)	High

[a]These goals are integrated with goals from other issues in the discussion of Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5, Tables 8.3.2.5-1 through 12). Site characterization-related design or performance parameters, their goals, and confidences are also established in these tables.

[b]ACGIH = American Conference of Governmental Industrial Hygienists.

Table 8.3.2.4-4. Performance measures, goals, and needed confidences for System Element 1.2.1.6 (mining ventilation) pertinent to Issue 4.2, nonradiological health and safety

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Provide adequate quantity of air to all work areas	Air quality, compliance with 30 CFR Part 57	125 CFM/horsepower of diesel equipment used for mining and mining support	High
		210 CFM/underground worker	High
		Minimum air velocity of 60 ft/min in all active work areas	High
Provide quality air to all work areas	Air quality, compliance with 30 CFR Part 57 and Threshold Limit Values (TLVs) and bioindices specified in ACGIH[b] (1986)	SiO_2 <0.1 mg/m^3	High
		O_2 concentration >19.5 vol%	
		CO <50 ppm time weighted average (TWA); short term exposure limit (STEL) <400 ppm	High
		Radon daughter concentration <1.0 working level (WL) in active work areas	High
		Personnel exposure to radon <4 working level months (WLM) annually	High
		Air cooling power >300 watts/m^2 at 45°C (dry bulb)	High

[a]These goals are integrated with goals from other issues in the discussion of Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5, Tables 8.3.2.5-1 through 12). Site characterization-related design or performance parameters, their goals, and confidences are also established in these tables.

[b]ACGIH = American Conference of Governmental Industrial Hygienists.

Table 8.3.2.4-5. Performance measures, goals, and needed confidences for System Element 1.2.2.5 (retrieval) pertinent to Issue 4.2, nonradiological health and safety (page 1 of 2)

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Provide access to emplacement borehole	Temperature in retrieval area	Surface rock temperature in shafts and ramps <35°C	High
		Temperature in access drifts <50°C (SRT)[b]	High
		Air temperature during retrieval <40°C	High
	Rock movement	Rock/support movement in accesses <1 mm/yr	Medium
		Rock movement in access drifts <1 mm/yr	Medium
		Rock movement in emplacement drifts <3 mm/yr	Medium
		Total closure in shafts <3 in. in 100 yr	Medium
		Total closure in ramps and drifts <6 in. in 100 yr	Medium
		Rockfall in ramps and drifts <5 ton/1,000 ft/yr	Medium
		Maximum rock or slab size <2 ton	Medium
		Rockfall in shaft <1/2 ton/1,000 ft/yr	Medium
		All rockfall (accesses and drifts) to be retained by support system (rock size >2 in. diameter)	High

Table 8.3.2.4-5. Performance measures, goals, and needed confidences for System Element 1.2.2.5 (retrieval) pertinent to Issue 4.2, nonradiological health and safety (page 2 of 2)

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Provide access to emplacement boreholes	Maintenance	Inspection and minor maintenance will be done on a continuing basis	Medium
		Major maintenance frequency >25 yr	Medium

[a]These goals are integrated with goals from other issues in the discussion of Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5, Tables 8.3.2.5-1 through 12). Site characterization-related design or performance parameters, their goals, and confidences are also established in these tables.

[b]SRT = Standard room temperature.

Table 8.3.2.4-6. Performance measures, goals, and needed confidences for System Element 1.2.2.7 (waste ventilation) pertinent to Issue 4.2, nonradiological health and safety

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Functions/processes and goals for waste ventilation are the same as those specified for System Element 1.2.1.6 (mining ventilation) except for the requirements for air cooling power and drift cooldown, which are specified below.			
Air quality	Air cooling power	Air cooling power required for inspection or light maintenance in waste emplacement area to be 300 watts/m^2 at 45°C (dry bulb) Air cooling power required for heavy maintenance or retrieval (emplacement drifts) to be 500 watts/m^2 at 40°C (dry bulb)	
Cooldown of rock for reentry of emplacement drifts to perform heavy maintenance or retrieval	Rock surface temperature	Surface rock temperature <50°C	

[a]These goals are integrated with goals from other issues in the discussion of Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5, Tables 8.3.2.5-1 through 12). Site characterization-related design or performance parameters, their goals, and confidences are also established in these tables.

Table 8.3.2.4-7. Performance measures, goals, and needed confidences for System Element 1.2.4.1 (underground closure) pertinent to Issue 4.2, nonradiological health and safety

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Backfill of drifts and installation of postclosure seals	Temperature	Air cooling power >500 watts/m^2 at 40°C (dry bulb)	High
		Rock surface temperature <50°C	Medium
		Air temperature <40°C	High
	Compliance with 30 CFR Part 57 and ACGIH[b] (1986)	SiO_2 concentration <0.1 mg/m^3	High
		O_2 concentration >19.5 vol%	
		CO <50 ppm time weighted average (TWA); short term exposure limit (STEL) <400 ppm	High
		Radon daughter concentration <1.0 working level month (WLM) in active work areas	High
		Personnel exposure to radon <4 working level months (WLM) annually	High

[a]These goals are integrated with goals from other issues in the discussion of Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5, Tables 8.3.2.5-1 through 12). Site characterization-related design or performance parameters, their goals, and confidences are also established in these tables.

[b]ACGIH = American Conference of Governmental Industrial Hygienists.

Table 8.3.2.4-8. Performance measures, goals, and needed confidences for System Element 1.2.5.6 (maintenance) pertinent to Issue 4.2, nonradiological health and safety

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Access (shaft and ramps) maintenance	Closure and rockfall	Rock movement	
		- <1 mm/yr	Medium
		- <3 in. total in shaft (100 yr)	Medium
		Rockfall	
		- <5 ton/1,000 ft/yr (ramp)	Medium
		- Maximum rock or slab size <2 tons	Medium
		- <1/2 ton/1,000 ft/yr (shaft)	Medium
		All rockfall >2 in. diameter retained by support system	Medium
Drift maintenance	Usability for 100 yr	Inspection and maintenance will be done on a continuing basis	Medium
		Major maintenance frequency >25 yr	Medium

[a]These goals are integrated with goals from other issues in the discussion of Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5, Tables 8.3.2.5-1 through 12). Site characterization-related design or performance parameters, their goals, and confidences are also established in these tables.

Table 8.3.2.4-9. Performance measures, goals, and needed confidences for System Element 1.2.5.9.2 (nonradiological monitoring) pertinent to Issue 4.2, nonradiological health and safety

Function/process	Performance measure	Tentative goal[a]	Needed confidence
Monitor usability of shafts, ramps, and drifts during construction, operation, retrieval, closure, and decommissioning	Items important to operational safety monitored and displayed in repository control center	Continuous monitoring of - Temperature - Rock movement - Rock support system (visual) - Air quality - Water inflow - Seismic activity	High

[a]These goals are integrated with goals from other issues in the discussion of Issue 4.4, preclosure design and technical feasibility (Section 8.3.2.5, Tables 8.3.2.5-1 through 12). Site characterization-related design or performance parameters, their goals, and confidences are also established in these tables.

Information Needs 4.2.2 and 4.2.3 do not result in the need for site data because they directly place constraints on Issue 4.4 where the data is collected (Section 8.3.2.5), and consequently, only the role of Information Need 4.2.1 will be addressed in the site characterization plan. The information specified as required by Information Need 4.2.1 will be used to resolve the issue of personnel safety related to design features and procedures that depend on site characteristics for analysis and assessment. Information Need 4.2.1 identifies the elements of the repository that present a potential safety hazard and outlines the analysis required to develop designs that will eliminate the potential hazard. The design techniques and the resulting designs are evaluated to determine that the goals specified by the issue resolution strategy are met. If the goals are met, then the issue is resolved.

The schedule information for Issue 4.2 (nonradiological health and safety) is presented in Section 8.3.2.4.2.

8.3.2.4.1 Information Need 4.2.1: Site and performance assessment information needed for design

Technical basis for addressing the information need

Issue 4.2 requires that the design and operating procedures be developed and demonstrated and that these procedures support resolution of the performance issue. Information Need 4.2.1 requires that the information needed to implement those procedures and develop the design be identified. To satisfy both the issue and information need, a two-part approach is proposed. Part 1 will address the issue of development and documentation of the design and operating procedures that are unique to repository design and require site-specific demonstration. Part 2 will identify the information needed to implement those procedures for the repository design, construction, and operation.

For Part 1, the development and documentation of the design and operating procedures, the following activities will be completed before license application: (1) initial designs and operating procedures will be developed and documented concurrently with the construction of the exploratory shaft facility (ESF), (2) the construction of the ESF will be monitored, (3) field experience and data collected during construction will be compared with design predictions for the range of conditions encountered in the ESF, and (4) the adequacy of the designs and operating procedures will be investigated. There will be some aspects of the repository design and operating procedures, particularly those related to worker health and safety during the potential retrieval, the closure, and the decommissioning phases, that cannot be demonstrated in the ESF; full-scale demonstrations of these aspects will be deferred to the performance confirmation area of the repository. The critical thermomechanical aspects of the design will be demonstrated by phenomenological and scaled tests in the ESF. The demonstrations and tests planned to verify the adequacy of the design and operating procedures will be addressed in the planned design activities section that follows the parameters section.

For Part 2, the information needed to implement the design and operating procedures is presented in the parameters section. Many of these parameters are the same as those identified for Issue 4.4, (preclosure design and technical feasibility, Section 8.3.2.5).

Link to the technical data chapters and applicable support documents

Chapter 6 describes the current repository conceptual design including excavation, development, and ground support (Section 6.2.6.1); ventilation (Section 6.2.6.3); and summarizes the status of this issue in Section 6.4.7. The information needed to address preclosure health and safety for the license application design (LAD) is identified in this section and in Issue 4.4 (Section 8.3.2.5). The establishment of the repository design and operating procedures will depend on observations and measurements made at the ESF. Performance Issue 4.1 (Section 8.3.5.7) dictates performance goals that must be addressed in this issue. Characterization programs 8.3.1.14, 8.3.1.15, 8.3.1.16, and 8.3.1.17 provide the parameter values required to address this issue.

Parameters

The parameters for this information need are as follows:

1. Information needed to design ground support in accessways and drifts. Parameters used to design the accessways and drifts and the design methods that use these parameters are presented in Information Need 4.4.7 (Section 8.3.2.5.7). Issue 4.4, Tables 8.3.2.5-1 through 12 indicate how well we need to know these parameters, which will be acquired from the ESF as well as other locations at the site. The ranges for parameter values listed in Issue 4.4 are compatible with the ranges required to resolve this issue. To ensure usability of the accesses and drifts during the potential retrievable phase and during decommissioning, an inspection and maintenance program will be maintained. Parameters listed in Issue 4.4 that relate to this issue include thermal, mechanical and thermomechanical properties of the intact rock, the joints and the rock mass, as well as the parameters for application of the empirical methods (such as rock quality designation, joint set number, joint roughness). The areal power density (APD) of the installed waste as well as the waste emplacement configuration will have a significant impact on the required maintenance program and consequently on worker safety. The information on APD and installed configuration of the waste will be obtained from Information Needs 1.11.3 and 1.11.6 (Sections 8.3.2.2.3 and 8.3.2.2.6), and the referenced preclosure design Information Need 4.4.5 (Section 8.3.2.5.5).

2. Information needed to design access ramps and drifts for safe movement of equipment, material, and personnel. A major consideration in safe movement of equipment, material, and personnel is the grades that must be negotiated. The following parameters are used in the determination of the repository design and hence the grades in the access ramps, main haulageways, access drifts, and emplacement drifts:

a. Site surface topography in the vicinity where surface facilities will be located.

b. Location of the upper and lower contacts for candidate disposal horizon. The location of the upper and lower contacts of the candidate disposal horizon should be established in areas where uncertainty exists that the thickness of the densely welded Topopah Spring Member (unit TSw2) is sufficient for safe construction and operation. The thickness of the unit TSw2 necessary to provide sufficient flexibility in selecting the depth of the underground facility has been established as 50 m. Consideration must also be given to the 200-m overburden requirement; the location of the unsaturated tuffs above the water table; the location of the contact between the relatively lithophysae-free and lithophysae-abundant tuff; stratigraphic zones of poor rock quality; and the location of the lower contact between the densely welded tuff and the basal vitrophyre.

c. Disposal horizon orientation (effective strike and dip). The disposal horizon effective strike and dip will be determined from the upper and lower contacts obtained from borehole data and data gathered during construction of the ESF.

d. Site surface geology. The site surface geology will be used to locate the portal for access shafts and ramps. The principal data needed is the location of exposed or near surface rock.

e. Location of site geologic structures. The geologic structures need to be identified for use in determining the location of shaft and ramp portals.

3. Information needed to plan safe construction techniques. The construction techniques and procedures to be used at the repository will be based on the characteristics of the repository site (e.g., the construction of drifts can be by conventional drill and blast methods or by mechanical mining machines); the method chosen will impact the procedures required to ensure worker safety. The information needed, with the required quality requirements, follows:

a. Rock properties needed to select mining methods, to size openings, and to design tunnel support. The properties required have already been identified under the design parameters needed for design of accessways and drifts (Issue 4.4, Section 8.3.2.5).

b. Formation water quantities. The presence of perched water reservoirs within the stratigraphic column penetrated by the shafts and ramps and within the disposal horizon could be a concern for worker safety. The site geology and existing data base do not suggest that significant perched reservoirs are located within the repository site at Yucca Mountain.

c. Potential for generation of hazardous respirable particulates. Actual types of particulates (e.g., silicates and asbestos form fibers) must be determined. Particulate sizes and quantities produced by various activities such as mining, crushing, drilling, and conveying must be determined. Size determination must quantify particulates that are equal to or smaller than the maximum size that can be carried or entrained by the repository ventilation flows.

4. Information needed to design the ventilation system (including data quality requirements) for dilution of natural, toxic, or hazardous gases. Gases in the mining horizons should be analyzed qualitatively and the actual gas types that may be encountered such as radon and methane should be determined. Worker safety information needs associated with radon are addressed in Issue 2.2 (worker radiological safety--normal conditions, Section 8.3.5.4). Existing data suggest that the occurrence of methane or other naturally occurring hazardous gases is unlikely and so no parameters specific to this need are identified.

   The occurrence of hazardous gases from underground operating equipment will impact the ventilation system. The qualification and typing of these gases does not require site data; thus, no parameters are required from the site.

5. Information needed to design the ventilation to provide adequate cooling to allow drift inspection, maintenance, waste retrieval, and decommissioning. A major worker safety concern during potential retrieval is the temperature of the working environment. In some instances it may be necessary to cool the drifts before retrieval or decommissioning operations to ensure a safe environment. The data required to design the necessary cooling system along with the requirement for data quality are as follows:

   a. Thermal conductivity of the rock.

   b. In situ temperature in the disposal horizon.

   c. Site meteorology. The diurnal and seasonal variations of the site relative humidity and temperature at the ventilation inlet and outlet locations are required.

   d. Moisture release rate from the drift and accessway surfaces.

   e. Ventilation airstream pressure loss as a function of drift length.

Logic

At this time it is possible to identify but not fully quantify all parameters needed to develop designs and operating procedures that will ensure worker nonradiological safety. Quantifying these parameters is an iterative process that begins with information obtained from preliminary investigations

at the site. This preliminary information will be verified or revised as dictated by new information obtained from tests conducted in the ESF. The information obtained from the ESF will be adjusted as required during construction of the repository to include additional data obtained on conditions not encountered in the limited extent of the ESF.

The following sections identify the subsurface activities that will be conducted during construction and subsequently in the repository to verify that the adopted design and operating procedures are adequate to protect worker health and to provide safe working conditions.

Two categories of tests and studies are identified: (1) those related to access and drift usability and (2) those related to ventilation and air quality. These two categories cover the major site data requirements related to nonradiological worker health and safety.

8.3.2.4.1.1 Design activity to verify access and drift usability

The methods and data used to develop the conceptual design of the repository are preliminary. The ESF offers an opportunity to verify these design techniques and to substantiate or provide the basis for adjustment of the design techniques used. The lateral extent of the ESF is expected to be sufficient to ensure that the demonstrated design techniques, the data obtained, and the test results will generally be applicable throughout the subsurface facilities with only minor modifications.

To demonstrate in the ESF that the design and operating procedures are adequate for repository design, the following demonstrations and tests will be conducted:

1. Demonstration of construction methods for accesses and drifts in tuff with emphasis on different lithophysae abundance, vitrification, and structural characteristics.

2. Characterization of the exposed rock. This characterization will be done to gain experience in the characterization methods proposed and to develop a data base that can be used to classify visually the rock encountered in the construction of the repository. The classification of the rock is the basis on which a particular ground support system will be specified during repository construction.

3. Demonstration of ground support installation for the various types of ground support proposed. The design of the ground support systems will include a number of types (e.g., rock bolts, rock bolts with wire mesh, shotcrete, and reinforced concrete). The types of support planned, based on currently available information, will be demonstrated.

4. Rock and support monitoring. Measurements of drift closure and support system loads will be made for the various rock types encountered and for the different support systems used. These

measurements in the exploratory shaft test facility will, in addition to providing beneficial data, be used to develop the measurements techniques and select instrumentation systems for use in the repository.

5. Test to compare ground support performance with performance predictions.

6. Test to simulate thermal/mechanical interactions to evaluate long-term ground support behavior.

7. Tests to validate the design models used to predict the performance of accessways and drifts.

The first five tests or demonstrations will verify the adequacy of the design and operating procedures for the construction of the repository; the last two tests address long-term considerations for ground support during waste emplacement, monitoring, maintenance, retrieval, closure, and decommissioning. These long-term considerations are difficult to evaluate by full-scale demonstration in the ESF; consequently, they may require a combination of laboratory tests, scaled field tests, model validation tests, and monitoring in the repository.

Additional details of the seven demonstrations and tests proposed for verification of the design and operating procedures are provided in the following:

1. Demonstration of construction methods. An evaluation of the influence of construction methods on worker safety and ground support requirements will be made. The evaluation will assess the effects of the selected and other candidate mining methods such as smooth-wall blasting and mechanical mining on the extent of the damaged zone, over-break, and support requirements. Tests will include the evaluation of the effects of blast hole pattern design, powder loading, and blasting agent type on safety and ground stability. Results of the blasting tests will be used to develop specifications and operating procedures for blasting in the repository. Monitoring of vibration effects due to blasting and the effect of the vibration on the ground support system will also be needed. The evaluation of the excavation techniques will be repeated for each significantly different ground classification.

2. Characterization of rock. Characterization of the rock will be performed in areas of the ESF where ground support system performance is monitored and where construction methods are evaluated. Characterization includes rock-quality designation, fracture spacing, fracture orientation, roughness, infill characteristics, intact rock compressive strength, internal-friction angle, tensile strength, moisture condition, permeability, and in situ stress as a function of distance from the excavated surfaces. These parameters will be evaluated for the various rock types encountered (provided the rock type dictates a revised support requirement). This information will be used to develop a catalog of rock types versus the required support for use in repository construction.

3. Support installation. The procedures for assessing ground conditions and selecting and installing the required ground support should be demonstrated during ESF construction. Those ground conditions for which the timing of ground support installation is critical should be identified.

4. Evaluation of the ground support system performance. The ground support systems should be monitored by observation, passive methods, and active instrumentation to evaluate performance. Rock bolt load history, shotcrete and concrete stress development, rock displacement, and rock stress changes should be monitored. Regions of rock stress relaxation and joint slip should be identified to assess the loads carried by the support system. The support systems should be monitored for all rock types encountered that dictate different support designs.

5. Comparison of ground support performance and design predictions. Design predictions will be based on empirical, analytical, and numerical techniques. Comparison of support performance and design predictions will involve site-specific modeling and the development of criteria for comparison and acceptance for both the analytical and empirical methods.

6. Simulation of thermal and mechanical interactions to evaluate long-term support behavior. Tests will be required to evaluate corrosion of ground support hardware, bolt anchor capacities at high temperatures, bonding characteristics between concrete or shotcrete and rock at high temperatures, and life expectancy of ground support systems for projection of maintenance requirements. A number of these tests could be conducted in a testing laboratory, while others will need to be done in scaled or full-sized test chambers in the ESF.

7. Tests to validate design models. Many aspects of the preclosure repository design associated with worker safety, specifically drift usability before closure, are based on the level of thermally induced stresses around the openings. Real-time demonstration of the design adequacy based on thermal effects in the repository will not be practical in the ESF. The fundamental basis for the design model, however, can be demonstrated by controlled full-size or scaled tests. Such tests would include

   a. Determination of the equivalent rock mass modulus, thermal expansion coefficient, and rock mass strength for the range of expected rock qualities.

   b. Determination of the influence of temperature on the rock mass properties in item a.

   c. Evaluation of large-scale joint properties such as joint stiffness (shear and normal), joint strengths (cohesion and friction angle), and the evaluation of the effects of temperature on these properties.

d. Demonstration of thermally induced rock deformation around canister and room configurations. These tests would be conducted in all significantly different rock types. The data from these tests would be compared with the results from the calculations based on the design models to develop confidence that the design procedures are correct.

8.3.2.4.1.2 Design activity to verify air quality and ventilation

Studies are required to assess the impact of site characteristics on the ventilation requirements necessary to provide a safe working environment. Site characteristics will determine dust quantities produced during construction, in situ gas types and quantities, and the wall roughness required for the ventilation flow calculations.

The influence of the construction method on dust generation and dust control methods can be evaluated during construction of the ESF. The drift roughness can be a function of the construction method, the rock quality, and the support system. Worker safety would be impaired if the factors contributing to surface roughness prevent the delivery of sufficient air to the working areas of the repository. Excessive roughness factors could dictate the need for larger drifts and the need for additional or larger ventilation supply and exhaust shafts. The parameters needed to properly design the ventilation system are as follows:

1. Air resistance factors as a function of wall roughness for the different rock types, construction methods, and support systems.

2. The in situ moisture in the rock. This will determine the water burden imposed on the ventilation system. The potential for dewatering versus temperature and the heat and moisture transfer into the ventilation system should be evaluated. The dehydration temperatures for the various rock types should be evaluated.

3. Formation gas types should be identified. Surface emission rates for the various types of gases present should be determined as a function of time after emission surface exposure and temperature.

4. Dust generation rates need to be determined for the different construction methods used and for the different types and qualities of rock encountered.

8.3.2.4.1.3 Application of results

The information identified under this information need provides the data base required to assess the adequacy of design and operating procedures for worker nonradiological health and safety. The information will serve as a part of the basis for DOE's demonstration of compliance with mining regulations, as required by the NRC.

8.3.2.4.2 Schedule for nonradiological health and safety (Issue 4.2)

Issue 4.2 (nonradiological health and safety) includes one information need, which contains two design activities. The schedule information for these design activities is summarized in Figure 8.3.2.4-2. This figure includes the design activity number and a brief description, as well as major events associated with each activity. A major event, for purposes of these schedules, may represent the initiation or completion of an activity, completion or submittal of a report to the DOE, an important data feed, or a decision point. Solid lines on the schedule represent activity durations and dashed lines show interfaces among activities as well as data transferred into or out of this design issue. The events shown on the schedule and their planned dates of completion are provided in Table 8.3.2.4-10.

The activity-level schedules, in combination with information provided in the logic diagram for this issue (Figure 8.3.2.4-1), are intended to provide the reader with a basic understanding of the relationships between major elements of the site, performance, and design programs. The information provided in Table 8.3.2.4-10 and Figure 8.3.2.4-2, however, should be viewed as a snapshot in time.

The overall program schedule presented here is consistent with the Draft Mission Plan Amendment (DOE, 1988a). The site characterization program will undergo a series of refinements following issuance of the statutory SCP. Refinements will consider factors both internal and external to the site characterization program, such as changes to the quality assurance program. Such refinements are to be considered in ongoing planning efforts, and changes that are implemented will be reflected in the semiannual progress reports. Summary schedule information for this and other repository design issues can be found in Sections 8.5.3 and 8.5.6.

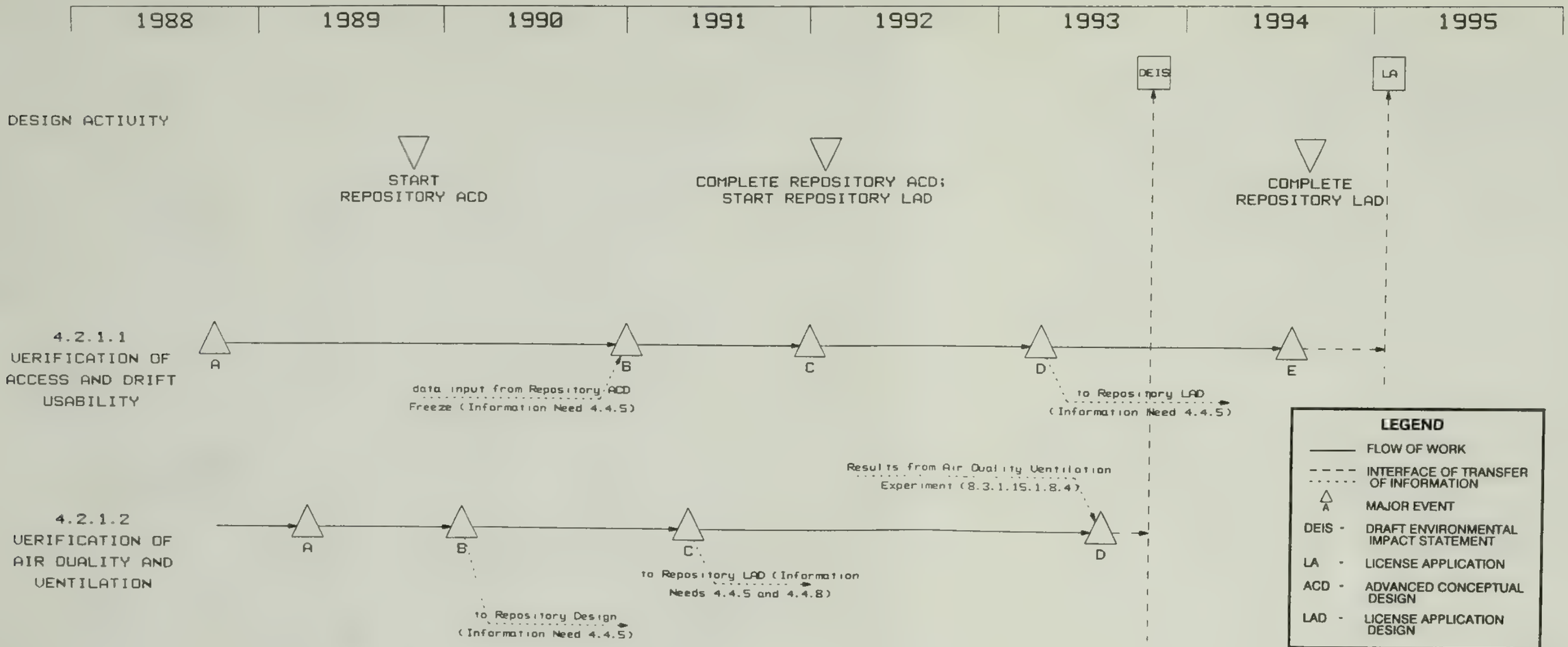


Figure 8.3.2.4-2. Schedule information for design activities in Issue 4.2 (nonradiological health and safety). See Table 8.3.2.4-10 for description of major events. This network is consistent with the Draft Mission Plan Amendment (DOE, 1988a) schedule. Revisions will be published in semiannual site characterization progress reports as new information becomes available.

Table 8.3.2.4-10. Major events and planned completion dates for activities in Issue 4.2 (nonradiological health and safety)

Design activity number	Brief description of design activity	Major event[a]	Event description	Date
4.2.1.1	Verification of access and drift usability	A	Continue design access and drift usability studies	10/88
		B	Site and design information input for access and drift usability studies	12/90
		C	Data on access and drift usability studies output to license application design (LAD)	12/91
		D	Data on access and drift usability output to surface facility LAD	3/93
		E	Complete studies to verify access and drift usability	7/94
4.2.1.2	Verification of air quality and ventilation	A	Complete design of activities to verify air quality and ventilation	3/89
		B	Data on air quality and ventilation activities output to LAD	1/90
		C	Data on air quality and ventilation activities output to surface facility LAD	4/91
		D	Complete design of activities to verify air quality and design	7/93

[a]The letters in this column key major events shown in Figure 8.3.2.4-2.

Nuclear Waste Policy Act
(Section 113)

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.2.5, Preclosure Design and Technical Feasibility

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.2.5 Issue resolution strategy for Issue 4.4: Are the technologies of repository construction, operation, closure, and decommissioning adequately established for the resolution of the performance issues?

Regulatory basis for the issue

Issue 4.4 (preclosure design and technical feasibility) questions whether the repository can be designed, constructed, operated, and closed using reasonably available or proven technology or if it will be necessary to extrapolate beyond current technologies in order to perform the functions identified by this issue. Many other constraints are imposed on this issue by other design or performance issues, including retrieval, postclosure design, and nonradiological health and safety concerns. Figure 8.3.2.1-1 in the overview section (8.3.2.1) depicts the relationship between this issue and the other design-related issues.

To avoid duplication, a careful division of responsibility between issues has been adopted. Issue 4.4 has been assigned the responsibility for the design of surface facilities and mined openings. Other issues will impose design requirements or constraints upon Issue 4.4 pertinent to their needs, and will receive the design and other input items (e.g., supporting analyses) back from Issue 4.4.

In a like manner, where it shares similar design requirements with another issue on a particular facet of the repository design, Issue 4.4 has been assigned the responsibility for developing the design, and providing the other three parts of the four-part design package (namely, the operating plan, supporting analyses, and any necessary demonstrations--see Figure 8.3.2.5-1). The related issue(s) provide requirements and constraints (and requests for other input items) to Issue 4.4 and receive the design package in return from Issue 4.4. Note that with this division of responsibility, Issue 4.4 requests most of the data on site characteristics. This division of responsibility is indicated in the logic diagrams and the supporting text and tables of the SCP sections discussing the design-related issues shown in Figure 8.3.2.1-1.

The regulatory basis for addressing this issue and the subsidiary information needs is contained in 10 CFR 60.133 and 10 CFR Part 960. Most of the parts of 10 CFR 60.133 that relate to the repository location, layout, and postclosure performance are addressed directly in Issue 1.11 (configuration of underground facilities (postclosure), Section 8.3.2.2). Some provisions of 10 CFR 60.133 relate to preclosure concerns, however. For example, 10 CFR 60.133(b) states that "the underground facility shall be designed with sufficient flexibility to allow adjustments when necessary to accommodate site-specific conditions identified through in situ monitoring, testing or excavation." Some of the "adjustments" might be required because of technology limitations such as the ability to predict rock behavior over the long life of the repository. Such limitations might result in a preclosure constraint from a postclosure criterion. Similarly, 10 CFR 60.133(f) states that "the design of the underground facility shall incorporate excavation methods that will limit the potential for creating a preferential path for ground water or radioactive waste migration to the accessible environment." This requirement places a potential constraint on the construction methods

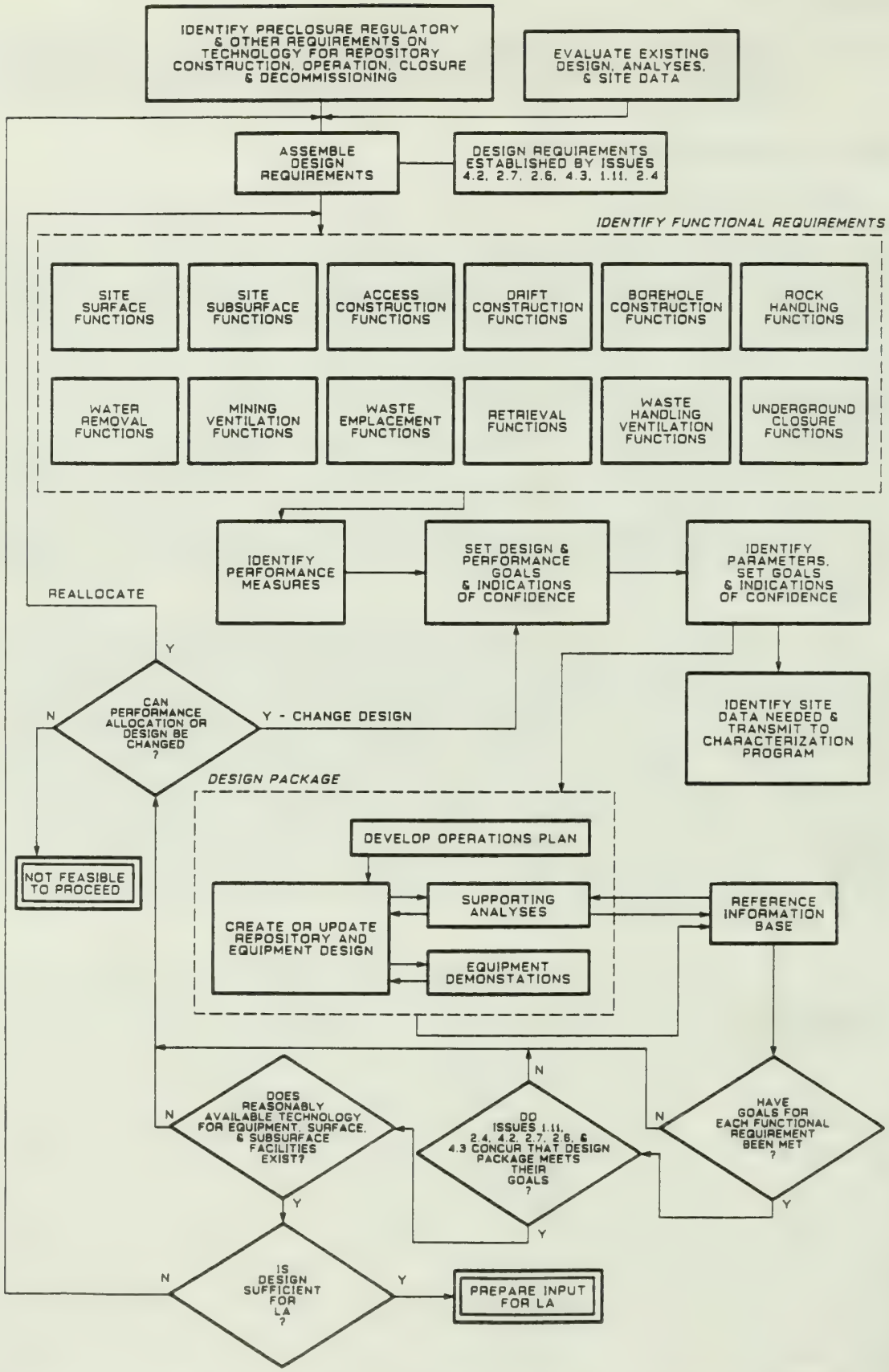
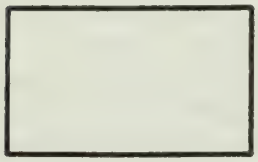
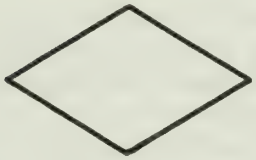


Figure 8.3.2.5-1a. Logic diagram for Issue 4.4 (preclosure design and technical feasibility). See Figure 8.3.2.5-1b for legend. Section 8.3.2.1 describes the relationships and interfaces between design and performances issues.

LEGEND



ACTIVITY PERFORMED TO RESOLVE ISSUE



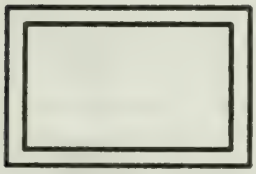
TEST TO DETERMINE SUBSEQUENT ACTIVITY



ACTIVITY PERFORMED BY INDICATED ISSUE



ACTIVITY WITH MULTIPLE SIMILAR ACTIVITIES OR TESTS



DECISION ABOUT ISSUE RESOLUTION

Y - YES N - NO LA - LICENSE APPLICATION

Figure 8.3.2.5-1b. Legend for Figure 8.3.2.5-1a.

and could impact this issue. The viability of these potential limitations and constraints will be determined during construction and subsequent testing in the exploratory shaft facility.

Other regulatory bases are contained in 10 CFR 60.131(b)(10), which applies to shaft conveyances used for waste transportation. These requirements will be applied as appropriate to features in the waste transport ramp that will be used to enhance safety.

The preclosure siting guidelines in 10 CFR Part 960 identify the potentially adverse condition, "In situ characteristics and conditions that could require engineering measures beyond reasonably available technology in the construction of the shafts and underground facility." This condition is addressed directly in this issue. This issue also covers the design questions related to the preclosure technical guidelines for surface and rock characteristics, hydrology, and tectonics.

Approach to resolving the issue

The approach used in resolving this issue is shown graphically in Figure 8.3.2.5-1. The approach, as it is applied to this issue, follows these steps:

1. The "system elements" of the Yucca Mountain mined geologic disposal system (MGDS) that are pertinent to the issue are selected from the total list of system elements given in Section 8.2. For Issue 4.4, only the preclosure elements are considered pertinent. Issue 4.3 (Section 8.3.4.4) addresses the technology requirements for waste package production, and so this element will not be considered in this issue. The site elements, surface and subsurface, could potentially require the use of advanced technology; consequently, they are considered in this issue. The elements, mining, waste handling, and decommissioning, are considered as potential candidates for the use of advanced technology in that they contain the bulk of the construction and operational activities. The performance confirmation and support system elements of the repository are not considered to require advanced technology; thus, they are not considered in this issue.

   Only System Elements 1.1.1 (surface) and 1.1.2 (subsurface) are physical items; the remaining system elements are activities. For this section, the remaining elements will be replaced by physical features in which the identified activities are performed (e.g., drift will be substituted for drift construction). For system elements such as retrieval the system element is used to identify limitations or goals for the performance of repository elements such as drifts and boreholes.

2. The functions and processes of the elements considered pertinent to design and to assessment of technical feasibility are identified. For these elements, the functions listed are those things that the element must do or provide for the repository to meet its required operational and functional goals. The list of functions is not all-inclusive. Only those functions that establish the technology

requirements within the specific system elements and require site-specific data to assess the need for new technology or technology development are identified. The criteria for whether a function plays a role in establishing technology requirements are as follows: (1) has the function been repeatedly demonstrated in normal industrial practices, (2) does the function depend only on engineered structures and equipment of predictable capabilities, and (3) does the function have a potential impact on worker health and safety?

3. The performance measure step identifies the required performance for the system element. Typical performance measures are temperature, rock movement, air flow, and maintenance frequency.

4. This step in the issue resolution strategy specifies the tentative performance goals and confidence needed in order to meet the performance measures. Performance goals are established to provide design guidelines. The goals are not always regulatory requirements; they are, however, based on meeting the applicable regulations.

5. The last step identifies the parameters needed to perform the analyses to determine if the performance goals can be met. It includes a tentative goal and an indication of expected values, needed confidence, and direct confidence.

The information needed to resolve this issue will be derived from the site or will be based on nonsite performance requirements. The criteria applied to distinguish those elements, and their included functions and processes, that require site data for the analysis of technology requirements are as follows:

1. Does the performance of the element depend on site environmental inputs (e.g., seismic and meteorological)?

2. Does the design of the element depend on site physical characteristics (e.g., topography, soil and rock strengths, and hydrology)?

Those elements that may require technology development but do not require site-specific data will be addressed in the repository design plan. The site data required for the analysis of the level of technology required will be defined in the information needs under this issue. These information needs will also establish the data quality requirements.

System elements

The Yucca Mountain mined geologic disposal system elements that were selected from the total set of elements listed in Section 8.2, as pertinent to this issue, are given in the following list. The elements that will be evaluated before the conclusion can be made that the repository can be constructed, operated, closed, and decommissioned using currently available technology are as follows:

System element	Name
1.1	Site
1.1.1	Surface
1.1.2	Subsurface
1.2	Repository
1.2.1	Mining
1.2.1.1	Access construction
1.2.1.2	Drift construction
1.2.1.3	Borehole construction
1.2.1.4	Rock handling
1.2.1.5	Water removal
1.2.1.6	Mining ventilation
1.2.2	Waste Handling
1.2.2.1	Receiving
1.2.2.2	Preparation
1.2.2.3	Storage
1.2.2.4	Emplacement
1.2.2.5	Retrieval
1.2.2.6	Shipping
1.2.2.7	Waste handling ventilation
1.2.2.8	Contamination control
1.2.4	Decommissioning
1.2.4.1	Underground closure
1.2.4.2	Surface facility decommissioning

The functions or processes for each of these elements are given in Tables 8.3.2.5-1 through 8.3.2.5-12. System elements 1.2.2.1 (receiving), 1.2.2.2 (preparation), 1.2.2.3 (storage), 1.2.2.6 (shipping), 1.2.2.8 (contamination control), and 1.2.4.2 (surface facility decommissioning) are not represented in tables but will be discussed in the repository design plan. These tables also include the performance measures used to evaluate performance in each element, the tentative performance goals, the needed confidences, and the performance or design parameters required to evaluate the technology requirements. Tentative goals, current confidences, needed confidences, and expected values are also provided for each performance or design parameter.

Interrelationships of information needs

The information needs for this issue identify the site parameters and the approach to integrating these parameters into designs and studies that demonstrate reasonable assurance of compliance with the performance goals and the regulatory requirements. Table 8.3.2.5-13 lists the information needs associated with this issue and the system elements addressed in each information need. Information Need 4.4.1 (Section 8.3.2.5.1) generally describes the parameter requirements developed in the other information needs under this issue.

The site parameters will be acquired through characterization programs for rock characteristics (Section 8.3.1.4), surface characteristics (Section 8.3.1.14), thermal and mechanical rock properties (Section 8.3.1.15), hydrology (Section 8.3.1.16), and tectonics (Section 8.3.1.17).

Table 8.3.2.5-1. Preliminary performance allocation for System Element 1.1.1, surface (page 1 of 6)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value
Provide sufficient area for surface facilities	Space to accommodate surface facilities (with contingency)	>100 acres for central surface facility	High	Surface topography at facility locations	Topographic maps with 1 m contours	Medium	Medium	1 m contours
		>50 acres for mined material storage	High	Surface topography at candidate mined material storage area	Topographic maps with 2 m contours	Medium	Medium	2 m contours
		>10 acres for each underground access location	Medium	Topography at underground access locations	Topographic maps with 1 m contours	Medium	Medium	1 m contours
		Minimum cut and fill	Medium	Topograpy of surface facility sites	Topographic maps with 1 m contours	Medium	Medium	1 m contours
Provide usable access for waste delivery vehicles	Grades for rail and truck delivery	<6% road grades <2% road grades	High	Surface topography on access routes	Topographic maps with 2 m contours	Medium	Medium	1 m contours
Provide facility sites (including underground accesses) that are not jeopardized by natural or manmade phenomena	Location relative to floodplain	Above floodplain	High	Topography at facility locations	Topographic maps with 1 m contours	High	Medium	1 m contours
				Surface hydrology for 5, 25, 50, 100, 500, yr flood and probable maximum flood (PMF)				
				Area of inundation	Inundation maps with elevation of inundation area to within ±2 m	High	Low	Area map with elevation of inundated area within ±2 m
					Secondary quantities used to derive area of inundation			
					Topography of drainage area 2 m contours	Medium	Medium	2 m contours
					Debris quantity and category	Low	Low	Cannot be estimated with currently available data
	Locations for surface facilities	Facilities important to safety (FITS) not located over potentially active geological structures	High	Identification of any fault within 100 m of FITS with greater than 1 chance in 100 of producing more than 5 cm of surface displacement in 100 yr	Determine existence	High	Low	No such faults are expected to be found

Table 8.3.2.5-1. Preliminary performance allocation for System Element 1.1.1, surface (page 2 of 6)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value
Provide facility sites (including underground accesses) that are not jeopardized by natural or manmade phenomena (continued)				If determined to exist, establish				
				Location at surface	Actual location to accuracy of ±5 m	High	Low	Location within 5 m
				Orientation at surface	Actual orientation to accuracy of ±10°	High	Low	Orientation to 10°
				Probability of exceeding 5 cm displacement under FITS	Probability of 5 cm displacement under FITS <.01 in 100 yr	High	Low	Probability <.01 in 100 yr
		Acceptable potential for vibratory ground motion	High	Design basis ground motion time histories and corresponding response spectra	Time histories and response spectra representative for exceptional earthquakes on nearby faults and underground nuclear explosions (for frequencies between 0.5 and 33 Hz)	Medium to high	Low	0.4-0.6g peak acceleration
				Potential for exceeding design basis ground motion at FITS	<0.1 probability in 100 yr	Medium to high	Low to medium	Probability <0.1 in 100 yr
				Probability vs. peak ground acceleration, peak ground velocity, and peak velocity response at selected frequencies at surface FITS locations	Values estimated for annual probability ranging from 10^{-2} to 10^{-6} per yr	Medium to high	Low	Cannot be estimated based on current data
		Acceptable potential for volcanic eruption at surface facilities	High	Probability of volcanic eruption that would disrupt surface facilities	Probability <.0001 in 100 yr	High	Medium to high	Probability <.0001 in 100 yr
		Design basis ash fall thickness at surface facility locations (including shaft and ramp portals)	Medium	Design basis ash fall thickness	<0.1 probability of exceeding design basis ash fall in 100 yr	Low to medium	Low	Probability <0.1 in 100 yr

Table 8.3.2.5-1. Preliminary performance allocation for System Element 1.1.1, surface (page 3 of 6)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value
Provide facility sites (including underground accesses) that have acceptable soil and rock conditions	Soil and rock conditions	Stable foundations on soil and rock under static load conditions	Medium	Allowable foundation bearing load pressure for soil considering shear failure and settlement (total and differential)	Allowable bearing pressure >0.2 MPa	Medium	Low to medium	0.2-0.4 MPa
				Allowable foundation bearing load pressure for rock considering shear failure and settlement (total and differential)	Allowable bearing pressure >14 MPa	Medium	Low to medium	21 MPa
		Stable retaining walls on soil and rock under static load conditions	Medium	Active and passive soil pressures for flexible and rigid structural walls	Earth pressure coefficient active >0.25 passive >3.4	Medium	Low	 0.27 3.70
				Active and passive rock pressure for flexible and rigid structural walls	Earth pressure coefficient active >0.25 passive >3.4	Medium	Low	 0.27 3.70
		Stable slopes for static and dynamic loading conditions	Medium to high	Factor of safety for an identified mechanism of potential slope failure in soil for static and dynamic loading conditions	For slopes potentially impacting FITS F.S.[b] >1.5 (static) F.S. >1.2 (dynamic)	High	Low	Cannot be estimated based on current data
					For slopes potentially impacting other structures F.S. >1.3 (static)	Medium	Low	Cannot be estimated based on current data
				Factor of safety for an identified mechanism of potential slope failure in rock for static and dynamic loading conditions	For slopes potentially impacting FITS F.S. >1.5 (static) F.S. >1.2 (dynamic)	High	Low	Cannot be estimated based on current data

Table 8.3.2.5-1. Preliminary performance allocation for System Element 1.1.1, surface (page 4 of 6)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value
Provide facility sites (including underground accesses) that have acceptable soil and rock conditions (continued)					For slopes potentially impacting other structures F.S. >1.3 (static)	Medium	Low	Cannot be estimated based on current data
		Suitable hydraulic related soil conditions considering infiltration/ runoff characteristics and erosion potential	Medium	Favorable infiltration: runoff ratio	See Section 8.3.1.2 (geohydrology)	High	Low	See 8.3.1.2
				Favorable hydraulic induced soil erosion characteristics	Scour around bridge piers <13 m in 100 yr	Medium	Low	See 8.3.1.6
					Bed erosion <5 m in 100 yr	Medium	Low	Cannot be estimated based on current data
					Sheet erosion <1 m in 100 yr	Medium	Low	Cannot be estimated based on current data
		Stable foundations on soil and rock for dynamic loading conditions (for FITS)	High	Favorable soil-structure interaction considering displacements and degree of yielding in soil beneath base of building[c]	Total displacement <3 in.	High	Low	Cannot be estimated based on current data
					Percentage of soil that has yielded beneath base of building <10%	High	Low	Cannot be estimated based on current data
				Favorable rock-structure interaction considering displacements and degree of yielding in soil beneath base of building[c]	Total displacement <3 in.	High	Low	Cannot be estimated based on current data
					Percentage of rock that has yielded beneath base of building <10%	High	Low	Cannot be estimated based on current data
		Stable retaining walls on soil and rock under dynamic loading conditions (for FITS)	High	Favorable soil-structure interaction considering displacements and degree of yielding in soil beneath base of building	Total displacement <6 in.	High	Low	Cannot be estimated based on current data
					Percentage of soil that has yielded beneath base of building <10%	High	Low	Cannot be estimated based on current data

Table 8.3.2.5-1. Preliminary performance allocation for System Element 1.1.1, surface (page 5 of 6)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value
Provide facility sites (including underground accesses) that have acceptable soil and rock conditions (continued)				Favorable rock-structure interaction considering displacements and degree of yielding in soil beneath base of building	Total displacement <2 in.	High	Low	Cannot be estimated based on current data
					Percentage of rock that has yielded beneath base of building <10%	High	Low	Cannot be estimated based on current data
		Soils not subject excessive volume change	Medium	Magnitude and rate of time dependent settlement in soils below earthfills[d]	Total settlement <4 in.	Medium	Low	Settlement <4 in.
				Magnitude of swell in subgrade soils below roads[d]	Total swell <1 in.	Medium	Low	Swell <1 in.
				Magnitude of soil collapse below surface facilities (foundations, earthfills, and roads) due to saturation and/or loading[d]	Total collapse <2%	Medium	Low	Cannot be estimated based on current data
					In situ density >90% of maximum dry density	Medium	Low to medium	Cannot be estimated based on current data
				Favorable soil liquifaction potential for saturated low density soils under dynamic loading conditions[d]	In situ density >85% of maximum dry density	Medium	Low to medium	Density >93.5%
					Well graded soil	Medium	Low to medium	Poorly graded gravel or silty gravel
Protection and confinement of operational activities	Facilities adequate to withstand natural weather phenomena without damage to functional capability	Facilities not damaged by weather extremes	High	Design wind load at surface facility locations (normal winds)	80 mph	Medium	Medium	80 mph
				Design basis tornado				
				Probability of occurrence	$<1 \times 10^{-7}$ per yr	Medium	Low	$<1 \times 10^{-7}$ per yr
				Maximum wind speed	180 mph (combined translational and rotational velocity)	High	Medium	<180 mph
				Maximum atmospheric pressure drop	0.7 psi	High	Low	0.7 psi

Table 8.3.2.5-1. Preliminary performance allocation for System Element 1.1.1, surface (page 6 of 6)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value
Protection and confinement and operational activities (continued)				Design snow load at surface facility locations	10-16 in.	High	Medium	14 in.
				Design precipitation rate at surface facilities	2-4 in./h	High	Medium	3 in./h
Provide proper environment for personnel and equipment	Proper environment for personnel and equipment under normal weather extremes	Heating and cooling design values	High	Heating and air conditioning design values	No site characterization data is required. Existing data from near vicinity locations is adequate if normalized to Yucca Mountain sites. Values will be developed and presented in the repository design plan.			
		Site location	Medium	Site locations	Coordinates of facility locations	Medium	High	Coordinates within ±5 m
		Site elevation	Medium	Site elevation	Elevations of surface facilities	Medium	High	Elevations within ±5 m

[a]Tentative goals, including ranges, for performance or design parameters are based on current reference values used to repository conceptual design and supporting analyses (Tables 6-11 through 6-16), and limited sensitivity analyses reported in Appendix I of the Site Characterization Plan-Concenptual Design Report (SNL, 1987) and its references and in Ehgartner (1986).

[b]F.S. = factor of safety.

[c]If the alluvium or rock adjacent to the foundation has shear velocities greater than 3,500 ft/s, then a soil-structure interaction analysis will probably not be necessary.

[d]The need for these design and performance parameters or characterization parameters is contingent on the soil and rock conditions encountered. On the basis of the preliminary soil and rock data from the site, these parameters are not currently required.

Table 8.3.2.5-2. Preliminary performance allocation for System Element 1.1.2, subsurface (page 1 of 5)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value[b]
Provide adequate area for distributing waste (with contingency) and required overburden	Area for 70,000 metric tons of waste and overburden >200 m	Goal for needed area established in Issue 1.11 (see Section 8.3.2.2 for needed site parameters)	High	See Issue 1.11, Section 8.3.2.2				
Provide underground sites (including accesses) that are not jeopardized by natural or manmade phenomena	Ability to continue preclosure operations and retrieve waste	Underground facilities not located in areas with a high probability of disruption by faulting	High	Identification and characterization of significant Quaternary faults in the repository block	Determine existence	High	Low	No such faults are expected to be found in repository, but two such faults bound block
				If determined to exist, establish				
				Location at repository level projected from surface data	Actual location to accuracy of ±20 m	High	Low	Cannot be estimated based on current data
				Orientation (strike and dip)	Actual orientation to accuracy of ±10°	High	Low	Cannot be estimated based on current data
				Probability of exceeding 7 cm displacement in areas of waste emplacement	Probability of 7 cm displacement in waste emplacement area <1 chance in 10 in 100 yr	Medium	Low	Probability <0.1 in 100 yr
		Acceptable potential for vibratory ground motion	High	Design basis ground motion time histories, and corresponding spectra at underground facility	Time histories and response spectra representative of 10,000-yr cummulative-slip earthquakes on nearby faults and underground nuclear explosions (for frequencies between 0.5 and 33 Hz)	Medium to high	Low	0.2-0.3g peak acceleration (subsurface)
			High	Combined potential for vibratory ground motion at underground facility locations	<1 chance in 10 of exceeding design basis ground motion in 100 yr	Medium to high	Medium to low	Probability <0.1 in 100 yr

Table 8.3.2.5-2. Preliminary performance allocation for System Element 1.1.2, subsurface (page 2 of 5)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value[b]
Provide adequate area for distributing waste (with contingency) and required overburden (continued)		Acceptable potential for volcanic eruption through underground facility	High	Probability of volcanic eruption through area of waste emplacement	Probability $<1 \times 10^{-6}$ per yr	High	Low	Probability $<1 \times 10^{-6}$
Provide host rock thickness for drift construction and waste emplacement	Thickness for drift construction and waste emplacement	Host rock thickness >50 m	High	Stratigraphic contacts for top and and bottom of the TSw2 formation within candidate areas for repository	Determine elevation of stratigraphic contacts at selected points within candidate repository area to accuracy of ±10 m (Note: goal is to determine potential usable extent of acceptable area based on this and other criteria)	High	Low	Thickness of TSw2 within area meeting other selected guidelines for repository horizon defined in Issue 1.11 (Section 8.3.2.2)
Provide physical properties adequate for construction and operation of stable (safe) underground accesses, drifts, emplacement boreholes, and support facilities for normal and credible abnormal conditions	Usable openings of required sites	Accessways and drifts usable for 100 yr	High	Rock properties in primary area				
				Poisson's ratio (intact rock)	TSw1 0.20-0.30 (NL)[c]	Low	Low to medium	0.20-0.30
					0.13-0.19 (L)[d]	Low	Low	0.13-0.19
					TSw2 0.19-0.29	Medium	Medium	0.19-0.29
				In situ stress (rock mass)	Vertical 6.3-7.7 MPa (average) value for 300 m)	Medium	Low to medium	6.3-7.7
					Minimum horizontal stress ratio 0.3-0.8	Medium	Low	0.3-0.8
					Maximum horizontal stress ratio 0.3-1.0	Medium	Low	0.3-1.0
					Bearing of minimum horizontal stress between N 50 E-N 65 E	Medium	Medium	N 50° W-N 65° W
					Bearing of maximum horizontal stress between N 25 E-N 40 E	Medium	Medium	N 25° E-N 40° E
				Initial temperature (rock mass)	TSw2 23-25°C	Medium	Medium	23-25°C
				Coefficient of thermal expansion (rock mass)	TSw1 current mean ±15% (NL and L)	Medium	Low to medium	12×10^{-6}/K
					TSw2 current mean ±15%	Medium	Medium	9×10^{-6}/K

Table 8.3.2.5-2. Preliminary performance allocation for System Element 1.1.2, subsurface (page 3 of 5)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value[b]
Provide physical properties adequate for construction and operation of stable (safe) underground accesses, drifts, emplacement boreholes, and support facilities for normal and credible abnormal conditions (continued)				Thermal conductivity (rock mass)	TSw1 current mean ±20% (NL) (Dry)	Medium	Low to medium	1.2 W/m-K
					TSw1 current mean ±20% (L) (Dry)	Medium	Low	0.8 W/m-K
					TSw2 current mean ±20% (Dry)	Medium	Low to medium	1.4 W/m-K
				Young's modulus (intact rock)	TSw1 12-54 GPa (NL)	Medium	Medium	19-44 GPa
					14-17 GPa (L)	Medium	Low	15.5 GPa
					TSw2 29-33 GPa	Medium	Medium	31 GPa
				Deformation modulus (rock mass)	TSw1 12-20 GPa (NL)	Medium	Low	12-20 GPa
					4-11 GPa (L)	Medium	Medium	4-11 GPa
					TSw2 11-19 GPa	Medium	Low	11-19 GPa
				Heat capacity	TSw1 current mean ±10% (NL) (saturated)	Medium	Low to medium	2.1 J/m^3-K
					current mean ±10% (NL) (dry)	Medium	Low to medium	2.0 J/m^3-K
					current mean ±10% (L) (saturated)	Medium	Low to medium	1.9 J/m^3-K
					current mean ±10% (L) (dry)	Medium	Low to medium	1.4 J/m^3-K
					TSw2 current mean ±10% (saturated) (dry)	Medium	Low to medium	2.2 J/m^3-K
				Unconfined compressive strength (intact rock)	TCw current mean ±20%		(see footnote e)	
					PTn current mean ±20%		(see footnote e)	
					TSw1 54-207 MPa (NL)	Medium	Medium	67-172 MPa
					13-19 MPa (L)	Medium	Medium	16 MPa
					TSw2 121-175 MPa	Medium	Medium	148 MPa
				Cohesion of rock and angle of internal friction -- intact rock (compressive strength as a function of confining pressure) fining pressure)	TCw cohesion, current mean ±20%	Medium	Low	30-70 MPa
					Angle of internal friction, current mean ±20%	Medium	Low	45°
					PTn cohesion, current mean ±20%	Medium	Low	4-12 MPa
					Angle of internal friction, current mean ±20%	Medium	Low	8-5°

Table 8.3.2.5-2. Preliminary performance allocation for System Element 1.1.2, subsurface (page 4 of 5)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value[b]
Provide physical properties adequate for construction and operation of stable (safe) underground accesses, drifts, emplacement boreholes, and support facilities for normal and credible abnormal conditions (continued)					TSw1 cohesion, current mean (NL & L) ±20%	Medium	Low	11-36 MPa
					Angle of internal friction, current mean (NL&L) ±20%	Medium	Low	12-35°
					TSw2 cohesion, current mean ±20%	Medium	Low	35 MPa
					Angle of internal friction, current mean ±20%	Medium	Low	24°
				Joint normal and shear stiffness properties (fractures)	TSw2		(see footnote e)	
				Joint wall compressive (fracture surfaces)	TSw2		(see footnote e)	
				Joint roughness coefficient (fracture surfaces)	TSw2		(see footnote e)	
				Cohesion and coefficient of friction (fractures)	TSw2 cohesion, current mean ±20%	Medium	Low	0.1 MPa
					Coefficient of friction, current mean ±20%	Medium	Low	0.54
				Number of joint sets	TSw2 2-3	High	Medium	2-3 sets
				Frequency and spacing	TSw2 20-40/m^3	Medium	Medium	20-40/m^3
				Joint orientation	TSw2 identify joint sets and orientation	Medium	Medium	Cannot be estimated based on current data
				Joint roughness and condition of joints	TSw2 discontinuous to smooth undulating	Medium	Medium	Rough, undulating
				Rock quality designation	TSw2 80-35	Medium	Medium	80-35
				Joint alteration	TSw2 softening or low friction with clay mineral coatings	Medium	Medium	Unaltered to slightly altered

Table 8.3.2.5-2. Preliminary performance allocation for System Element 1.1.2, subsurface (page 5 of 5)

Function or process	Performance measure	Tentative Goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value[b]
Provide physical properties adequate for construction and operation of stable (safe) Underground accesses, drifts, emplacement boreholes, and support facilities for normal and credible abnormal conditions (continued)				Construction method	No site data required			
				Presence of swelling or squeezing ground	Not present based on current data			
				Water inflow	Quantify water inflow	Medium	High	Not expected
				Expected seismic loading	0.2-0.3g acceleration	Medium	Low	0.2-0.3g (underground)
				Description and frequency of abnormal conditions in rockmass	TBD	TBD	TBD	TBD
				Fault properties (subsurface)				
				Location	Actual location to accuracy of ±5 m	High	Low	Location within 5 m
				Orientation	Actual orientation to accuracy of ±10°	Medium	Medium	Orientation to within 10°
				Physical, thermal, and mechanical properties of major faults	Offset ±2 m Spacing ±1 m Fill characteristics	High	Low	Cannot be estimated based on current data
Dissipate heat from emplaced waste	Waste package temperature	Centerline temperature of waste package <350°C	High	Initial formation temperature	See values specified under rock properties in primary area			
				Thermal conductivity of rock	See values specified under rock properties in primary area			
				Heat capacity of rock	See values specified under rock properties in primary area			
Provide adequate water for repository operations	Available water	Water availability >400 acre-ft per yr	High	Sustained yield of pumped water source for operational support	400 acre ft/yr	Medium	Medium	>400 acre ft/yr

[a]Where the goal is indicated as a percentage of the current mean value, the goal is to show that the distribution of the new data is similar to that of the current data and that the mean value of the new data lies within the range specified as percentage of the current mean value. The goals are based on current values used for repository conceptual design and supporting analyses (Tables 6-11 through 6-16) and limited sensitivity analyses reported in Appendix I of the Site Characterization Plan-Conceptual Design Report (SNL, 1987) and in Ehgartner (1986).

[b]In general the expected value is provided to indicate the range of typical values measured to date. This column is not intended to identify the limits of all values measured to date nor is it intended to indicate that the design would be invalid if future values obtained differ from the values presented.

[c]NL denotes properties for nonlithophysal.

[d]L denotes properties for lithophysal.

[e]Existing data are insufficient to establish goals or expected values.

Table 8.3.2.5-3. Preliminary performance allocation for system element 1.2.1.1, access construction (page 1 of 4)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Underground facility access for personnel, support materials, waste handling systems during construction, operation (including retrieval), and decommissioning	Accesses (shafts and ramps) usable for 100 yr with reasonable maintenance	Access to construct, emplace, and retrieve waste, close, and decommission for 100 yr	High	The parameters required, the tentative goals, and confidence required for these parameters are the same as those listed under System Element 1.1.2 subsurface, under rock properties in primary area				
	Compliance with 10 CFR 60.133f	Limit rock damage during construction		The parameters required, the tentative goals, and confidence required for these parameters are the same as those listed under System Element 1.1.2 subsurface, under rock properties in primary area				
		Overbreak <6 in. average	Medium					
		Extent of fracturing of intact rock <3 m average	Medium					
	Access closure (combined performance of rock and opening support system)	Extent of closure		The parameters required, the tentative goals, and confidence required for these parameters are the same as those listed under System Element 1.1.2 subsurface, under rock properties in primary area				
		<1 mm/yr in accesses (shafts and ramps)	Medium					
		Total closure <6 in. in 100 yr (ramps)	Medium					
		Total closure <3 in. in 100 yr (shafts)	Medium					
	Rockfall	Rockfall		The parameters required, the tentative goals, and confidence required for these parameters are the same as those listed under System Element 1.1.2 subsurface, under rock properties in primary area				
		<5 ton (average) per 1,000 ft of length per yr (ramps)	Medium					
		Maximum size of rock or slabfall <2 tons	Medium					
		Rockfall contained by support system (ramps)	Medium					
		No rockfall to disrupt or damage waste transporter (ramp)	Medium					

Table 8.3.2.5-3. Preliminary performance allocation for system element 1.2.1.1, access construction (page 2 of 4)

Function or process	Performance measure	Tentative Goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Underground facility access (continued)		Rockfall or liner spall in shafts <1 ton (average) per 1,000 ft/yr	Medium					
		All rockfall or liner spall in shaft to be retained (by supplemental support system, supplemental liner or other methods)	High					
	Maintenance frequency	Inspection and maintenance frequency		The parameters required, the tentative goals, and confidence required for these parameters are the same as those listed under System Element 1.1.2 subsurface, under rock properties in primary area				
		Inspection and minor maintenance done on continuing basis	Medium					
		Major maintenance frequency <25 yr	Medium					
	Access sizes and grades compatible with requirements for personnel and material transport and utility routing	Size			No site characterization data required			
		20 ft clear diameter man and material shaft to accommodate man and material cage of required capacity and utilities	Medium					
		19 ft diameter waste ramp roadway width 5 ft > width of waste transporter. Minimum vehicle clearance >2 ft	Medium					

Table 8.3.2.5-3. Preliminary performance allocation for system element 1.2.1.1, access construction (page 3 of 4)

Function or process	Performance measure	Tentative Goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Underground facility access (continued)		20 ft diameter tuff ramp clearance adequate for tuff conveyor, movement of major construction equipment and utilities	Medium					
		Grades		Elevation at ramp entry ramps	Topographic maps with 1 m contours	Medium	Medium	1 m contours
		Waste ramp grade <10%	High					
		Tuff ramp grade <20%	Medium					
Ventilation routing (supply and exhaust)	Pressure drop in shafts and ramps	Shafts and ramps of sufficient size to limit flow velocities. Size sufficient to provide contingency to cover changes in future air quantity requirements		Pressure drop per unit length of drift	Site data required will be pressure drop measurements made in shafts and ramps constructed in different types of rock. Measurements wills be repeated for each construction method and liner type used.			
		Ramp velocities <1,500 ft/min	Medium					
		Shaft velocities <3,000 ft/min	Medium					
Sealing	Shafts and ramps compatible with requirements for repository sealing	Materials used compatible with sealing requirements	High		Parameters (information needed) have been identified under Issue 1.12, Table 8.3.3-9.			
		Construction methods compatible with sealing requirements	High		No site characterization data required			
		ES-1 shaft liner capable of being removed at time of closure	High		No site characterization data required			

Table 8.3.2.5-3. Preliminary performance allocation for system element 1.2.1.1, access construction (page 4 of 4)

Function or process	Performance measure	Tentative Goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Sealing (continued)		No shaft (except ES-1) should penetrate into Calico Hills unit	High	Elevation of upper Calico Hills	Elevation within 5 m	High	High	At ES-2 = 2,728 ft; at men and materials shaft = 2,742 ft; at waste ventilation shaft = 2,806 ft
		Water storage capacity at base of shafts (excluding ES-2) to be 150 m^3	High		No site characterization data required			
		The thickness between the bottom of ES-1 or any exploratory shaft facility (ESF) drifting and the ground-water table should be greater than the minimum thickness of the Calico Hills above the water table anywhere within the repository boundary	High	Ground water table 2,400 ft elevation at ES-1		High	High	2,400 ft

Table 8.3.2.5-4. Preliminary performance allocation for System Element 1.2.1.2, drift construction (page 1 of 2)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Underground facility access for personnel, support materials, waste handling systems during construction, operation (including retrieval), and decommissioning	Drifts usable for 100 yr with reasonable maintenance	Access to construct, emplace and retrieve waste, close and decommission for 100 yr	High	The parameters required for these performance goals for System Element 1.2.1.2 are the same as specifed under rock properties in primary areas under System Element 1.1.2 (subsurface)				
	Compliance with 10 CFR 60.133f	Limit rock damage during construction		The parameters required for these performance goals for System Element 1.2.1.2 are the same as specified under rock properties in primary areas under System Element 1.1.2 (subsurface)				
		Overbreak <6 in. average	Medium					
		Extent of fracturing in intact rock <3 m	Medium					
	Drift closure (combined performance of rock and rock support system)	Extent of closure		The parameters required for these performance goals for System Element 1.2.1.2 are the same as specified under rock properties in primary areas under System Element 1.1.2 (subsurface)				
		<1 mm/yr in main and access drifts	Medium					
		<3 mm/yr in waste emplacement drifts	Medium					
		Total closure <6 in. in 100 yr for all drifts	Medium					
	Rock fall (performance of rock support system)	Rockfall		The parameters required for these performance goals for System Element 1.2.1.2 are the same as specified under rock properties in primary areas under System Element 1.1.2 (subsurface)				
		<5 ton (average) per 1,000 ft of drift per yr	Medium					
		Rockfall contained by support system	High					
		Maximum size of rock or slab fall <2 tons	Medium					
		No rockfall sufficient to disrupt or damage waste transporter	Medium					
	Acceptable maintenance frequency	Frequency		The parameters required for these performance goals for System Element 1.2.1.2 are the same as specified under rock properties in primary areas under System Element 1.1.2 (subsurface)				
		Inspection and minor maintenance will be done on a continuing basis	High					

Table 8.3.2.5-4. Preliminary performance allocation for System Element 1.2.1.2, drift construction (page 2 of 2)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Underground facility access (continued)		Major maintenance frequency >25 yr	High				Medium	
	Drift sizes and slopes compatible with requirements for personnel and material transport and utility routing	Drift cross-section 6 ft greater than maximum mobile equipment width	Medium	No site characterization data required				
		Drift grades <8%	High	Upper and lower contact elevations for the TSw2 formation over the entire repository area	Upper and lower contact elevations for the TSw2 within 20 m	Medium		Elevations accurate to ±20 m
Ventilation routing (supply and exhaust)	Pressure drop in drifts	Drifts of sufficient size to limit air velocities to <2,000 ft/min	Medium	No additional site characterization data required. Site data requirements related to nonradiological health and safety are identified in Table 8.3.2.5-8 under System Element 1.2.1.1, mining ventilation				
Sealing	Drifts (underground layout) compatible with repository sealing	Underground drift layout and grades should provide water drainage from waste emplacement to designated nonemplacement drifts	High	Upper and lower contact elevations for the TSw2 formation within the potential repository area	Upper and lower contact elevations for the TSw2 within 20 m	Medium	Medium	Elevations accurate to ±20 m
		Drift layout and and grades within the exploratory shaft facility should drain to the ES-1 shaft	High	Upper and lower contact elevations for the TSw2 formation within the potential repository area	Upper and lower contact elevations for the TSw2 within 20 m	Medium	Medium	Elevations accurate to ±20 m

Table 8.3.2.5-5. Preliminary performance allocation for System Element 1.2.1.3, borehole construction

Function/ process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal[a]	Needed confidence	Current confidence	Expected value
Provide for emplacement	Constructability of usable borehole for waste disposal envelope	25 ft deep x 29 in. diameter vertical borehole	High	Abrasiveness of rock	Reasonable cutter life	Medium	Medium	Cannot be estimated based on current data
		363 ft long x 36 in. diameter horizontal borehole	High	The additional parameters required to access constructability of usable boreholes are the rock parameters identified under System Element 1.1.2 (subsurface)				
Provide waste emplacement envelope	Installation of borehole liner	Ability to install vertical hole liner	High	Mechanical systems---No additional site characterization data required				
		Ability to install up to 363 ft of horizontal hole liner	High	Mechanical systems---Because the longitudinal boreholes are lined as they are drilled, no additional site characterization data required				

[a]Tentative goals, including ranges, for performance or design parameters are based on current reference values used for repository conceptual design and supporting analyses (Tables 6-11 through 6-16), and limited sensitivity analyses reported in Appendix I of the Site Characterization Plan-Conceptual Design Report (SNL, 1987) and its references and in Ehgartner (1986).

Table 8.3.2.5-6 Preliminary performance allocation for System Element 1.2.1.4, rock handling

Function/ process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Removal of mined rock	Ability to remove mined rock at rate of generation	3,000 tons/day	Medium	Size range of blast-fractured rock	Maximum rock size	Low	Low	<12 in.
				Angle of repose of fractured rock piles	Actual angle of repose ±5°	Low	Low	25-30°

Table 8.3.2.5-7. Preliminary performance allocation for System Element 1.2.1.5, water removal

Function/ process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Removal of process water	All process water removed	Removal capacity >600 gph	Medium	Quantity of process water	(a)			
Removal of natural water	Removal rate equal to rate of inflow	Removal capacity >50 gpm	Medium	Natural water inflow	Actual inflow rate to accuracy of ±10 gpm	Medium	Low	<50 gpm
Removal of water resulting from condensation in ventilation returns (potential during operations)	Removal rate equal to rate of condensation	Removal capacity > potential rate of condensation	Medium	Condensate quantity	(b)			

[a]No site characterization data required. Values will be developed in the plan for repository design.
[b]Condensate potential and quantities will be determined using parameters specified in System Elements 1.1.2 (subsurface), 1.2.1.6 (mine ventilation), and 1.2.2.7 (waste handling ventilation).

Table 8.3.2.5-8. Preliminary performance allocation for System Element 1.2.1.6, mining ventilation (page 1 of 2)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Supply quality air to working area (considering: temperature, humidity, dust content, and other pollutants)	Compliance with 30 CFR Part 57	125 ft^3/min per unit diesel horsepower in use	High	In situ temperature of host rock	TSw2 23-25°C	Medium	Medium	23-25°C
	Compliance with threshold limit values and biological exposure indices specified in ACGIH[a] (1986)	Normal operation air cooling power = 300 w/m^2 at 45°C (dry bulb)	High	Diurnal temperature and humidity variation of ambient air at intake and exhaust locations	Temperature/ humidity vs. time-of-day plots for year (based on historical data)	No site characterization data required. Existing data sufficient when normalized to site		
		210 ft^3/min per worker	High					
		60 ft/min minimum air velocity in work areas	High	Seasonal temperature and humidity variation of ambient air at intake and exhaust locations	Temperature/ humidity vs. time-of-day plots for year (based on historical data)	No site characterization data required. Existing data sufficient when normalized to site		
				Surface topography at intake and exhaust locations	Topographic maps with 1 m contours	Medium	Medium	1 m contours
				Pressure drop/unit length of accesses or drifts	Actual pressure drop for rock exhibiting different surface characteristics and for each method of construction	Low	Low	(b)
		Silicon dioxide particulate concentration <0.1 mg/m^3	High	Rock chemistry	Potential for SiO_2	Medium	Medium	SiO_2 content of rock
				Dust generation potential for mining and drilling operations	Particulate size and quantity data	Medium	Medium	(c)
		Oxygen concentration >19.5 volume percent	High	Equipment type and utilization times	No site characterization data required			
		Radon daughter concentration <1.0 working level (WL) in active working area (Issues 2.2 and 2.7)	High	Potential for radon	Rock uranium content	Medium	Medium	(c)
				Radon emission rate from rock	Radon emission rate	Medium	Medium	(c)

Table 8.3.2.5-8. Preliminary performance allocation for System Element 1.2.1.6, mining ventilation (page 2 of 2)

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Supply quality air to working area (considering: temperature, humidity, dust content, and other pollutants) (continued)		Personnel exposure to radon daughters <4 WL months (Issues 2.2 and 2.7)	High	Potential for radon	Rock uranium content	Medium	Medium	(c)
				Radon emission rate from rock	Radon emission rate	Medium	Medium	(c)
Provide flexibility to allow changes in air quantities and routing	System design flexibility to allow changes in air quantities and routing	Flexibility in design of layout and flow control features (regulators and stoppings)	High	Underground design	No site characterization data required			
Provide safe escape routes for work force	Ventilated escape routes available for all active work areas	Ventilated escape routes provided by design	High	Underground design operation plan	No site characterization data required			
Provide independence between ventilation systems	Compliance with 10 CFR 60.133(g)	Drift layout and contructed features (bulkheads, airlocks, etc.) designed to ensure independence of systems	High	Underground design	No site characterization data required			
		Leakage to be from mining ventilation to waste emplacement ventilation system	High	Permeability of disturbed rock	Permeability of rock affected by mining operations (blasting)	Low	Low	(c)
				Pressure differentials between systems	No site characterization data required			

[a]ACGIH = American Conference of Governmental Industrial Hygienists.
[b]No estimate available. Values used to this point for ventilation calculations have been based on handbook information.
[c]Cannot be estimated based on currently available data.

Table 8.3.2.5-9. Preliminary performance allocation for System Element 1.2.2.4, emplacement

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Transport waste to emplacement location	Ability to transport the required number of waste packages per day using methods that will ensure personnel safety	Transport 10 packages per day	High	Mechanical activity--no site characterization data required				
		Nonradiological safety (Issue 4.2)	High	Parameters pertinent to nonradiological safety that are dependent on site characteristics are presented under System Element 1.2.1.1 (access construction) and System Element 1.2.1.2 (drift construction)				
	Compliance with ALARA[a] Compliance with other requirements relating to worker radiation dose[b]	Radiological safety (see Issue 2.7 for radiological safety goals, Issue 2.2 for normal conditions, and Issue 2.3 for accident conditions)	High	Parameters pertinent to radiological safety that are dependent on site characteristics are presented under System Element 1.2.2.5 (retrieval)				

[a]ALARA = as low as reasonably achievable.
[b]The goals and parameters required to develop assurance of worker radiological safety are discussed and presented in detail in Sections 8.3.5.4, 8.3.5.5, and 8.3.2.3.

Table 8.3.2.5-10. Preliminary performance allocation for System Element 1.2.2.5, retrieval

Function or process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Retrieval of emplaced waste	Access to emplacement borehole	Access available for 100 yr with reasonable maintenance of accesses and drifts	High	Access to the emplaced waste for retrieval will be ensured by setting the goals for rock damage, closure, and rockfall stipulated in Systems Elements 1.2.1.1 (access construction) and 1.2.1.2 (drift construction). The parameters needed to predict performance of the accesses and the drifts are specified in System Element 1.1.2 (subsurface)				
	Access to waste package	Rock temperature at borehole wall <275°C	Medium	Access to the emplaced waste for retrieval will be ensured by meeting the goals for rock damage, closure, and rockfall stipulated in Systems Elements 1.2.1.1 (access construction) and 1.2.1.2 (drift construction). The parameters needed to predict performance of the accesses and the drifts are specified in System Element 1.1.2 (subsurface)				
		Borehole liner deformation <2 in. vertical emplacement, <3 in. for horizontal emplacement (in 100 yr)	Medium	Access to the emplaced waste for retrieval will be ensured by meeting the goals for rock damage, closure, and rockfall stipulated in Systems Elements 1.2.1.1 (access construction) and 1.2.1.2 (drift construction). The parameters needed to predict performance of the accesses and the drifts are specified in System Element 1.1.2 (subsurface)				
		Liner corrosion <1/2 liner thickness in 100 yr	Medium	Water and formation chemistry	Quantitative and qualitative analysis of formation and water	Medium	Medium	Cannot be estimated based on current data
Waste retrieval	Retrieval time	Retrieval time < emplacement time plus construction time	Medium	Operations plan	No site characterization data required			
	Operator safety	Radiation dose rate for retrieval operations personnel <1 rem/yr	High	Radiation shielding characteristics of rock	Attenuation factors for neutron and gamma radiation	Medium	Medium	Cannot be estimated based on current data
Waste transport	Operator safety	Radiological safety[a]	High	Radiation shielding characteristics of rock	Attenuation factors for neutron and gamma radiation	Medium	Medium	Cannot be estimated based on current data
		Nonradiological safety[a]	High	Operations plan	No site characterization data required			

[a]The goals and parameters needed to develop assurance of worker radiological safety are identified and discussed in detail in Sections 8.3.5.4, 8.3.5.5, and 8.3.2.3.

Table 8.3.2.5-11. Preliminary performance allocation for System Element 1.2.2.7, waste handling ventilation

Function/ process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Supply air to waste disposal areas during emplacement and retrieval	The performance measures, goals, and needed confidences for this function are the same as for System Element 1.2.1.6 (mining ventilation) except for the addition of cooling requirements to provide for retrieval of waste packages from heated drifts, the additional requirement is			Site data required for this System Element is the same as the data required by System Element 1.2.1.6				
	Air cooling power for retrieval or preparation	Air cooling power for retrieval or retrieval preparation = 500 W/m^2 at 40°C (Dry Bulb)	High					
Radiological safety	Detection of airborne radioactive material	Immediate detection of airborne radioactive materials	High					
	Reduction and redirection of vent flows in the event that airborne radioactive particulate is detected	Reduction of ventilation flow by 50%	High					
		Diversion of ventilation flow to filter system	High					
Provide flexibility to allow changes in air quantities and routing necessary to accommodate changes in requirements	Performance measures and goals are the same as System Element 1.2.1.6 (mining ventilation)							
Provide safe escape routes for work force	Performance measures and goals are the same as System Element 1.2.1.6 (mining ventilation)							
Provide independence between ventilation systems	Performance measures and goals are the same as System Element 1.2.1.6 (mining ventilation)							

Table 8.3.2.5-12. Preliminary performance allocation for System Element 1.2.4.1, underground closure

Function/ process	Performance measure	Tentative goal	Needed confidence	Performance or design parameter	Tentative goal	Needed confidence	Current confidence	Expected value
Removal of repository structures	Compliance with requirements for decommissioning	Decommissioning operations and designs compatible with postclosure requirements	High	Parameters needed are identified in System Elements 1.1.1 (surface) and 1.1.2 (subsurface). Requirements will be identified in the decommissioning section of the operations plan and the repository design plan				
Installation of seals	Compliance with requirements for postclosure seals	Preclosure designs compatible with requirements for postclosure seal installation	High	Parameters required are identified in System Elements 1.1.2 (subsurface), 1.2.1.1 (access construction), and 1.2.1.2 (drift construction), and Issue 1.12, Table 8.3.3-8				
		Preclosure and decommissioning materials compatible with postclosure seals	High	Parameters required are identified in System Elements 1.1.2 (subsurface), 1.2.1.1 (access construction), and 1.2.1.2 (drift construction), and Issue 1.12, Table 8.3.3-8				
		Seals installed per requirements of sealing program	High	Parameters required are identified in System Elements 1.1.2 (subsurface), 1.2.1.1 (access construction), and 1.2.1.2 (drift construction), and Issue 1.12, Table 8.3.3-8				
Installation of surface markers	Marker permanence	Marker lifetimes equal to requirements	Medium	Parameters needed are identified in System Elements 1.1.1 (surface) and 1.1.2 (subsurface). Requirements will be identified in the decommissioning section of the operations plan and the repository design plan				
Construction of diversion structures or water flow barriers	Construction according to sealing requirements	Lifetime and material requirements met	Medium	Parameters needed are identified in System Elements 1.1.1 (surface) and 1.1.2 (subsurface). Requirements will be identified in the decommissioning section of the operations plan and the repository design plan				
Installation of backfill	Filling of all underground openings	Openings filled with materials acceptable to waste package performance requirements	High	Parameters required are identified in System Elements 1.1.2 (subsurface), 1.2.1.1 (access construction), and 1.2.1.2 (drift construction), and Issue 1.12, Table 8.3.3-8				
		Openings filled with materials meeting sealing requirements	High	Parameters required are identified in System Elements 1.1.2 (subsurface), 1.2.1.1 (access construction), and 1.2.1.2 (drift construction), and Issue 1.12, Table 8.3.3-8				

Table 8.3.2.5-13. System elements for the Yucca Mountain mined geologic disposal system addressed by each information need (page 1 of 2)

Information need	Short title	System elements
4.4.1	Site and performance assessment information needed for design	ND[a]
4.4.2	Waste package information needed for design	Addressed in repository design plan (RDP)
4.4.3	Plans for repository operations	ND
4.4.4	Repository design requirements	ND
4.4.5	Reference preclosure repository design	1.1.1 Surface 1.1.2 Subsurface
4.4.6	Equipment development and demonstration	Addressed in RDP
4.4.7	Design analyses	1.1.1 Surface 1.1.2 Subsurface 1.2.1.5 Water removal
4.4.8	Technology for surface facility	1.1.1 Surface
4.4.9	Technology for underground facilities	1.1.2 Subsurface 1.2.1.1 Access construction 1.2.1.2 Drift construction 1.2.1.3 Borehole construction 1.2.1.4 Rock handling 1.2.1.5 Water removal

Table 8.3.2.5-13. System elements for the Yucca Mountain mined geologic disposal system addressed by each information need (page 2 of 2)

Information need	Short title	System elements
4.4.9 (continued)		1.2.1.6 Mining ventilation 1.2.2.4 Emplacement 1.2.2.5 Retrieval 1.2.2.7 Waste-handling ventilation 1.2.4.1 Underground closure
4.4.10	Technology seals emplacement	1.2.4.1 Underground closure

[a]ND = no data available.

The determination of whether the repository can be constructed, operated, closed, and decommissioned using reasonably available technology will be based on the technology requirements for each system element. The technology requirements will be developed by a design process for the element that includes configuration determination, design analysis (requiring site and nonsite data) and material selection to meet the performance goals for that element. The assessment that the technology is reasonably available will be based on the following criteria:

1. Have the proposed construction techniques been successfully used in other applications?

2. Have similar performance goals been met in other subsurface facilities with thermal conditions, hydrologic conditions, and rock characteristics like those predicted for the repository?

3. Have the operations required for the repository been used and proved at other installations?

4. Can the technology for construction, prediction of performance, and operation of the repository be demonstrated before license application to ensure its successful application in the repository?

5. Can a combination of empirical, observational, and analytical techniques be used that will give reasonable assurance that the design will meet the performance goal?

The exploratory shaft facility can be used to demonstrate technology. A further demonstration of technology will be possible in the initial phases of repository construction and in the performance confirmation area of the repository.

The schedule information for Issue 4.4 (preclosure design and technical feasibility) is presented in Section 8.3.2.5.11.

8.3.2.5.1 Information Need 4.4.1: Site and performance assessment information needed for design

This information need summarizes the site-related parameters identified as being required by the remaining information needs under this issue. Specifically, the required information is derived from the design analyses, reference design development, equipment program needs, operations plan, subsystems design requirements, and assessments of reasonably available technology. Both surface and underground data and parameters that have potentially significant effects on design and performance will be included. Tables 8.3.2.5-1 through 8.3.2.5-12 provide specific information regarding these parameters, including an indication of the confidence needed in the parameter values.

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

Section 6.1 of this document summarizes the design basis for the repository, including the design requirements, reference design data base, and approaches and tools used for design. Section 6.2 describes the current design of the repository. In addition, Section 6.4 documents the current status of analyses completed to date that use much of the data. On the basis of these sections, the following observations can be made:

1. Properties of surface material and rock at or near the surface can have an impact on the design of surface facility structural foundations.

2. Soil and rock conditions, as well as topographic relief, can influence the specific locations selected for the surface facilities and underground entrances.

3. Repository surface and subsurface facilities must be designed to withstand ground motion associated with earthquakes and underground nuclear tests that might occur at the site vicinity during their operational lifetime. The facilities will be designed to withstand ground motion associated with a natural earthquake with a recurrence time greater than 1,000 yr. Such ground motion is expected to be larger than that resulting from underground nuclear testing. The ground motion resulting from underground nuclear testing is, therefore, expected to be bounded by a design based on the larger ground motion associated with natural seismicity. In addition, because of the presence of a number of faults in the site vicinity, the potential for surface rupture during the operational period will be considered in choosing the final location for the surface facilities.

4. Rock characteristics can impact construction and operation affecting stability, mineability, and the operating environment (e.g., humidity, drift temperatures, and air quality).

The SCP Conceptual Design Report (SCP-CDR) (SNL, 1987) summarizes the design bases in Chapter 2, provides a detailed description of design and operations in Chapters 3, 4, and 5, and, for convenience, reproduces the SCP discussions (See 6.4) regarding the status of resolving Issue 4.4 in Chapter 8.

Parameters

The parameters needed to address this information need have been identified in detail and are listed in Tables 8.3.2.5-1 through 8.3.2.5-12 according to the applicable system element.

Logic

This section briefly presents the justification for specifying the parameters identified in Section 8.3.2.5, Tables 8.3.2.5-1 through 8.3.2.5-12.

The surface facilities must be located where the underlying soil and rock conditions provide adequate strength without undue settlement of structural foundations. Hence, soil and rock mechanical properties are needed for the foundation design.

Soil-structure interaction can significantly affect the seismic forces on the surface structures. To determine these effects, the shear wave velocity profile, shear modulus, damping, and Poisson's ratio data are needed.

Topographic, local meteorological, and upland drainage data, together with soil and rock characteristics, alternative locations, and right-of-way, etc., will be combined to determine flooding potential at the site, acceptable configuration of the facilities, problems to the site, and cut and fill estimates. Meteorological data are also required to design the underground ventilation system.

Ground motion at the site from man-made and natural seismic events is important in the location and design of surface facilities. Information about potential igneous activity, ground motion, and fault movements that could result in surface rupture is important for evaluating the design of both the surface and underground facilities. Any active faults that are close to the repository will be evaluated for their potential to produce ground motions and possible rupture during the operational period. The surface and subsurface facilities will need to be designed to tolerate these ground motions, and the effects of surface rupture will need to be considered.

The properties and behavior of the host rock, surrounding strata, and ground-water systems are very important for the preclosure and postclosure period design requirements of the underground facilities. Rates and magnitudes of igneous activity at the site are important for the postclosure period to determine potential impacts on containment and isolation of radioactive wastes. Hydrologic characteristics at the site are also very important for seal designs.

The mineability of the rock units at Yucca Mountain is being investigated through a series of mining demonstrations. The exploratory shaft and test facilities will be used to demonstrate mineability. Site data to satisfy this part of the information need is the mineability demonstration. Results of the demonstration will establish data on mining and drilling rates that can be used to evaluate cost effectiveness and technical feasibility.

Factors important for working environment considerations in design that depend upon rock characteristics are (1) drift rock wall temperature, (2) drift wall wetness factor, (3) any water inflow into the drift, and (4) air quality (dust, radon, etc.). Air quality is investigated in other information needs and is not considered under this information need. Dust is addressed in Information Need 4.2.1 (site performance information needed for design, Section 8.3.2.4.1), and the potential for radon emanation from the host rock is addressed in Information Need 2.2.1 (natural radiological environment, Section 8.3.5.4.1).

Data for water inflow into the drift will be used to design the drainage and pumping systems. Although significant inflows are not expected, the underground facility will be designed to accommodate anomalous conditions. The drainage system will control the flow of water so that water will not collect at places such as emplacement boreholes (a condition that would be adverse to performance). The pumping system will remove any excess water accumulating at collection points and move it to the surface. This information need merely identifies this data requirement and passes it to the water supply investigation described in Section 8.3.1.16.3.

Drift wall wetness factor is required for ventilation system design because it reflects humidity in the drift. An assumed value is currently being used, and analysis of the environment of the exploratory shaft facility (ESF) areas will allow an assessment of whether the assumed value correctly predicted the amount of water vapor that enters the drift. This will require monitoring air flows and humidity within ESF areas.

There are no planned design activities for this information need. Data required to satisfy this information need are identified in Section 8.3.2.5.7. Related design activities will be discussed in the discussions of the other information needs under this issue. An updated set of reference values is planned for issuance at or near the start of each major design phase (advanced conceptual design, license application design, and final procurement and construction design). Designers will use the reference values or justify why other than reference values have been used.

For the field testing, technical procedures will be developed using control methods similar to those of NRC Regulatory Guides and American Society for Testing and Materials standards. Quality assurance requirements to be used will be consistent with the DOE Quality Assurance Program, as described in Section 8.6.

8.3.2.5.1.1 Application of results

The information generated from this information need (4.4.1) will be used to support resolution of Issue 4.4 by providing information needed by Information Need 4.4.2, (waste package information needed for design) through Information Need 4.4.10 (technology for seals construction), to update the reference information base for use in the license application design, and to provide guidance in planning the data gathering program for the Yucca Mountain Project.

8.3.2.5.2 Information Need 4.4.2: Characteristics and quantities of waste and waste packages needed for design

This information need serves as an important interface between the waste package design and the repository design. No site data are required to satisfy this information need. The information is identified here for completeness and because the waste information has a major impact on the surface

and underground facilities of the repository. The data identified in the information need is used throughout this issue.

This information need is considered satisfied when waste package-repository interface requirements have been finalized and passed to the subsystems design requirements document for use by designers and analysts. Updates of this information are planned for each successive phase of the design process.

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The reference design of the waste package is discussed in Chapter 7. In Section 6.1, the waste and waste package information used in conceptual design of the repository is identified.

Parameters

The following is a listing of the waste-related parameters needed for the design of the repository. The source for obtaining these parameters is identified and discussed in the section that follows.

1. Waste quantities, including

    a. Spent fuel--number of disposal canisters, disposal packages, individual fuel elements, and quantities of waste hardware if consolidation is performed.

    b. Defense high-level waste--number of waste packages.

    c. West Valley waste--number of waste packages.

2. Thermal and radiation output plus thermal and radiation decay characteristics of waste forms.

3. Waste package design, size, weight, material, wall thickness, and the configuration of internal structures.

4. Waste package design restrictions for temperature, static and dynamic loading, and materials compatibility.

Logic

The conclusion that the repository can be constructed, operated, closed, and decommissioned using available technology will be developed by design analyses. A major factor affecting the design and the analyses is the quantity and character of the waste. The waste package quantities and characteristics are required to establish facility and equipment shielding requirements, to assess the potential of damage to materials or alteration of materials by radiolysis, and to determine the thermal input to the repository. Waste package quantities and receipt rates are required to estimate the size of the waste handling facilities, to determine the amount of waste

handling equipment needed, to prepare the waste for emplacement, and to emplace and retrieve the waste.

The logic supporting the selection of the specific parameters identified in the previous section is as follows:

1. Waste quantities are required to size the surface and underground facilities and to determine the need for waste preparation and handling equipment.

2. The thermal decay characteristics of the waste form affect the allowed areal power density (APD) for waste emplacement. This information will be used to

   a. Determine the total area required for the projected waste inventory and to develop the layouts for the underground waste emplacement area (Information Need 1.11.3, underground facility orientation and layout, Section 8.3.2.2.3). The use of this information is described in Section 6.4.5.

   b. Predict time-dependent temperatures and stresses for Information Need 1.11.6 (Section 8.3.2.2.6) and design analyses for Information Need 4.4.7.

3. Thermal output of the waste package will be used as an input to predict thermal and thermomechanical response of the host rock, surrounding strata, and ground-water system (Information Need 1.11.6). These information needs will provide rock temperatures which will be used to

   a. Establish inspection procedures and instrumentation for inspecting emplaced waste.

   b. Establish ventilation requirements for the repository operational period and for retrieval.

   c. Calculate rock-mass stresses and displacements as a part of opening stability analyses. These analyses will be used as a part of the basis upon which retrievability can be ensured starting at any time up to 50 yr after waste emplacement operations are initiated (Information Need 2.4.6 (compliance with retrieval requirements, Section 8.3.5.2.6)). Opening stability analysis is described in Information Need 4.4.7.

   d. Determine the moisture load on the ventilation system due to in situ moisture migration caused by the rock thermal gradient. This moisture migration will affect ventilation design (Information Need 4.4.7).

   e. Evaluate the potential for corrosion on the various elements of the waste emplacement envelope (liner, shield plug, closure).

   f. Set temperature criteria for design of the hardware and equipment used to support waste emplacement and retrieval.

4. Radiation output of the waste package will be needed to

   a. Establish emplacement hole depths so that adequate rock is available to provide sufficient shielding to limit operational personnel dose rates to design values. This need contributes to Information Need 2.7.1 (radiological protection, Section 8.3.2.3.1).

   b. Provide input to material radiation damage analyses and studies related to radiolysis of materials.

5. Waste package size will be needed to define the emplacement envelope and to design the waste package handling equipment (Information Need 4.4.6). The waste emplacement envelope consists of the emplacement borehole and borehole liner, the shield plug, the hole closure, and any materials used external to the liner for liner strength enhancement or corrosion retardation.

6. Waste package material will dictate to a significant extent the materials used in construction of the underground facility. The waste package material will preclude the use of materials in the vicinity of the waste package that may have a significant deleterious effect on the waste package. Items potentially affected are the borehole liner, liner grout, and concrete used in the preparation of the emplacement site. This information will also be an input to design Information Need 1.10.3 (reference emplacement configuration, Section 8.3.4.2.3), Information Need 1.4.2 (material properties of containment barrier, Section 8.3.5.9.2), and Information Need 1.4.3 (scenarios and models needed, Section 8.3.5.9.3).

7. Waste package design information will be used to

   a. Evaluate the ability of the waste package to withstand loads imposed by emplacement and normal or abnormal retrieval conditions (Information Need 4.4.6).

   b. To size the equipment used underground to support emplacement and retrieval (Information Need 4.4.6).

   c. To evaluate scenarios for breaching the reference waste package (Information Need 1.4.3).

8. Waste package temperature limits will be used to determine the emplacement borehole spacing. Spacings determined by consideration of waste package temperature will then be used to develop the underground repository layout for Information Need 1.11.3 and in Information Need 1.11.6. The methods for using this information to address these information needs are in Section 6.4.2.

9. Methods and information sources used to develop the required parameters include the following:

a. The waste quantities will be provided by the DOE in the generic requirements document. These quantities are based on a compilation of the current waste inventories and projections of future fuel usage.

b. The thermal decay and thermal output of the waste will be calculated using codes like the Oak Ridge ORIGEN II code, which is an isotope generation code that follows the decay chain of each specimen produced in the fission of uranium. This information will be used to define the specific decay and thermal characteristics for all waste types. Codes will include the effect of fuel burnup.

c. The radiation output of the waste package will be determined by analyses that consider the waste package geometry, the waste package design, and waste characteristics such as type, burnup, and age. Analyses of this type are typically done using codes that apply Monte Carlo techniques. No specific codes have yet been identified.

d. The information pertaining to the waste package size, material, and design will be obtained from Information Need 1.10.2 (reference waste package designs).

e. The waste package temperature will be limited by the maximum fuel cladding temperature for spent fuel and by the temperature of devitrification for defense high-level waste.

Analyses will be performed to update the information required by this information need as the repository design proceeds through the planned design phases and as more up-to-date information is obtained relating to waste quantities, waste characteristics, and waste package designs.

8.3.2.5.2.1 Application of results

The information provided by this information need will be used in the following issues and information needs:

Issue or information need	Short title	SCP section
1.11.7	Reference postclosure underground designs	8.3.2.2.7
2.1	Public radiological exposures--normal conditions	8.3.5.3
2.2	Worker radiological safety--normal conditions	8.3.5.4
2.3	Accidental radiological releases	8.3.5.5

Issue or information need	Short title	SCP section
2.4	Waste retrievability	8.3.5.2
4.4.3	Plans for repository operation	8.3.2.5.3
4.4.4	Repository design requirements	8.3.2.5.4
4.4.5	Reference preclosure repository design	8.3.2.5.5
4.4.6	Equipment development and demonstration	8.3.2.5.6
4.4.7	Design analyses	8.3.2.5.7
4.4.8	Technology for surface facilities	8.3.2.5.8
4.4.9	Technology for underground facilities	8.3.2.5.9
4.4.10	Technology for seals emplacement	8.3.2.5.10

8.3.2.5.3 Information Need 4.4.3: Plan for repository operations during construction, operation, closure, and decommissioning

A plan for repository operations is needed to effectively design and evaluate the preclosure performance of a waste repository. This information need will produce such a plan. No site data not already required by another information need is required for this plan; hence, the operations plan will only be briefly discussed in the SCP and will be more thoroughly described in the repository design plan (RDP).

Preliminary design and waste package information are combined with equipment concepts to produce flow diagrams and time-line diagrams that form the basis for the operations plan for conceptual designs. In each succeeding design phase, more detail becomes available for each required operation. The operations plan is updated to reflect the added detail and to reflect design decisions during each design phase (i.e., advanced conceptual design, license application design, and final procurement and construction design). The plan and the accompanying staffing levels and quantities of required equipment become an important part of the basis for completing safety analyses, cost estimates, environmental impact analyses, retrievability evaluations, and equipment design.

This information need is considered to be satisfied when successive versions of the operations plan are published for use as design guidance.

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

Chapter 6 describes most of the repository operations. In Section 6.1, general requirements (e.g., amounts and types of incoming wastes, and receipt

rates) for the repository are identified; the operations for waste emplacement and retrieval are identified in Section 6.2; and Section 6.4.8 identifies the progress made to date on the operations plan development.

In the SCP conceptual design report (SCP-CDR), the design bases are given in Chapter 2 and the repository operations are discussed in Chapter 3 and parts of Chapter 4. Chapter 8 of the SCP-CDR provides a brief synopsis of the operations plans published to date.

Parameters

The principal information that serves as input to the development of a plan for repository operations is as follows:

1. Waste-related information (Information Need 4.4.2, waste package information needed for design).

    a. Quantities.
    b. Receipt rates.
    c. Manufacturing processes.
    d. Inspection procedures.
    e. Reference transportation cask designs.

2. Reference repository design.

    a. Preclosure (Information Need 4.4.5, reference preclosure repository design).

    b. Postclosure (Information Need 1.11.7, reference postclosure underground designs, Section 8.3.2.2.7).

3. List of equipment and their performance (design) requirements (Information Need 4.4.6, equipment development and demonstration).

4. Abnormal conditions anticipated for repository operations (Information Need 4.4.3, plans for repository operation).

Logic

The starting point for development of an operations plan is a description of the material (nuclear waste) to be handled, the receipt rate for this material, and how the material will be delivered to the facility (reference transportation packages or shipping casks). This information is then coupled with concepts for the facility (reference designs of surface and underground facilities) and concepts for the handling equipment (receiving equipment, packaging equipment, transporter, and support equipment) to produce block flow diagrams for waste-related operations. These basic waste flow diagrams are then combined with similar diagrams for numerous repository support systems (mining, muck removal, monitoring, etc.) to produce overall repository material flow diagrams.

Time-line diagrams are then developed that can be used along with the flow diagrams to (1) determine important operational information (amount of equipment, normal throughput, maximum capacity, etc.); (2) develop tradeoff

studies to assess what system operational flexibility is gained by various combinations of waste receipt, available equipment, and operations sequences; (3) determine staffing levels for the repository; and (4) provide input for accident and cost analyses.

After the list of planned operations is developed for normal conditions, the differences in operations needed for specific scenarios that define abnormal conditions can be added. This assessment of operations under credible abnormal conditions often leads to the identification of needs for special equipment or procedures to be used.

The operations plan becomes more detailed with each successive design phase (advanced conceptual design, license application design, final procurement and construction design) as more and more information is available and as design decisions are made concerning both facilities and equipment.

A major revision of the operations plan will therefore be needed for each design phase. These major revisions comprise the two planned activities to be completed under this information need.

8.3.2.5.3.1 Design Activity 4.4.3.1: Operations plan to accompany the advanced conceptual design

Objectives

The objective of this design activity is to produce an operations plan to accompany the advanced conceptual design (ACD).

Description

This version of the operations plan will be published during ACD. The principal focus for the plan will be the waste handling operations (including retrieval) since these operations will be detailed as input to preliminary safety evaluations and to the establishment of scenarios for credible abnormal conditions.

8.3.2.5.3.2 Design Activity 4.4.3.2: Operations plan to accompany the license application design

Objectives

The objective of this design activity is to produce an operations plan to accompany the license application design (LAD).

Description

This version of the operations plan will be published during LAD. It will contain the results of design decisions made during ACD and will contain

operations only for the selected emplacement option. This version will contain sufficient detail for all repository operations to allow both radiological and nonradiological safety analyses to be conducted.

8.3.2.5.3.3 Application of results

There are numerous uses for the operations plans. The numerous issues and information needs that will use the plans are given in the following list. The way in which the operations plans will be used is briefly described following the list.

Issue or information need	Short title	SCP section
2.1	Public radiological exposures--normal conditions	8.3.5.3
2.2	Worker radiological safety--normal conditions	8.3.5.4
2.3	Accidental radiological releases	8.3.5.5
2.4	Waste retrievability	8.3.5.2
2.7	Repository design criteria for radiological safety	8.3.2.3
4.2	Nonradiological health and safety	8.3.2.4
4.4.6	Equipment development and demonstration	8.3.2.5.6
4.4.7	Design analyses	8.3.2.5.7
4.4.8	Technology for surface facilities	8.3.2.5.8
4.4.9	Technology for underground facilities	8.3.2.5.9
4.4.10	Technology for seals emplacement	8.3.2.5.10

The repository designers will use the plans to design both the surface and underground facilities. Similarly, equipment designers will use the plans to provide the hardware capable of carrying out the required operations. Analysts will use the plans for ventilation calculations and safety tradeoff studies in support of Information Need 4.4.7. Finally, the plans will be used as part of the basis for assessments of reasonably available technology for surface facilities, underground facilities, and for seals construction.

In addition, Issue 2.4 will use the (1) flow diagrams; (2) time lines; (3) quantities of required equipment; and (4) reliability, availability, and maintainability information to evaluate retrieval schedules, develop scenarios for abnormal conditions, and evaluate the capability to retrieve the waste. Similar data are required for safety evaluations performed in Issues 2.1, 2.2, 2.3, and 2.7 to assess the performance of the design relative to specified criteria and allowable exposures to workers and the public under normal and accident conditions. The nonradiological health and safety evaluation covered in Issue 4.2 will also use the operations plans to develop accident scenarios. Finally, time diagrams, staffing levels, and equipment quantities produced in the plan will serve as reference input for the development of repository cost estimates.

8.3.2.5.4 Information Need 4.4.4: Repository design requirements for construction, operation, closure, and decommissioning

Design requirements or criteria are needed to guide the repository design. These requirements must reflect guidance from regulations, program level guidance, project level guidance, and site-specific information. As indicated in Figure 8.3.2.5-2, regulations applicable to a nuclear waste repository and guidance from the DOE have been combined to produce program level guidance in the form of a generic requirements document (DOE, 1986c). Project level guidance in the form of system requirements follow from the generic requirements. At the designer level, repository design requirements (RDR) are developed. The content of these requirements documents and the hierarchical relationship between them is shown schematically in Figure 8.3.2.5-2.

This information need is considered to be satisfied by the publication and control of the RDR applicable to each phase of the design of the repository. Controlled assumptions and the baseline design configuration will be clearly documented and maintained in the RDR.

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

Section 6.1 identifies the design basis used to develop the SCP conceptual design report (SCP-CDR) (SNL, 1987). Section 6.2 shows the design resulting from this basis, and Section 6.4 indicates the status of work completed to date that establishes the requirements in the RDR. Chapter 2 of the SCP-CDR contains a more detailed discussion of the bases for the SCP conceptual design.

Parameters

The following requirements in the following lists will be considered in the generation of the RDR for use by repository designers.

Federal government requirements include

1. Nuclear Waste Policy Act of 1982 (NWPA, 1983).

2. Mission Plan (DOE, 1985b).

3. NRC, DOE, EPA, U.S. Department of Transportation (DOT), Mine Safety and Health Administration (MSHA) Code of Federal Regulations examples include

    a. 10 CFR Part 60.
    b. 10 CFR Part 960.
    c. 40 CFR Part 191.
    d. 30 CFR Part 57.
    e. 49 CFR Parts 171 through 177.
    f. CFR Part 20.

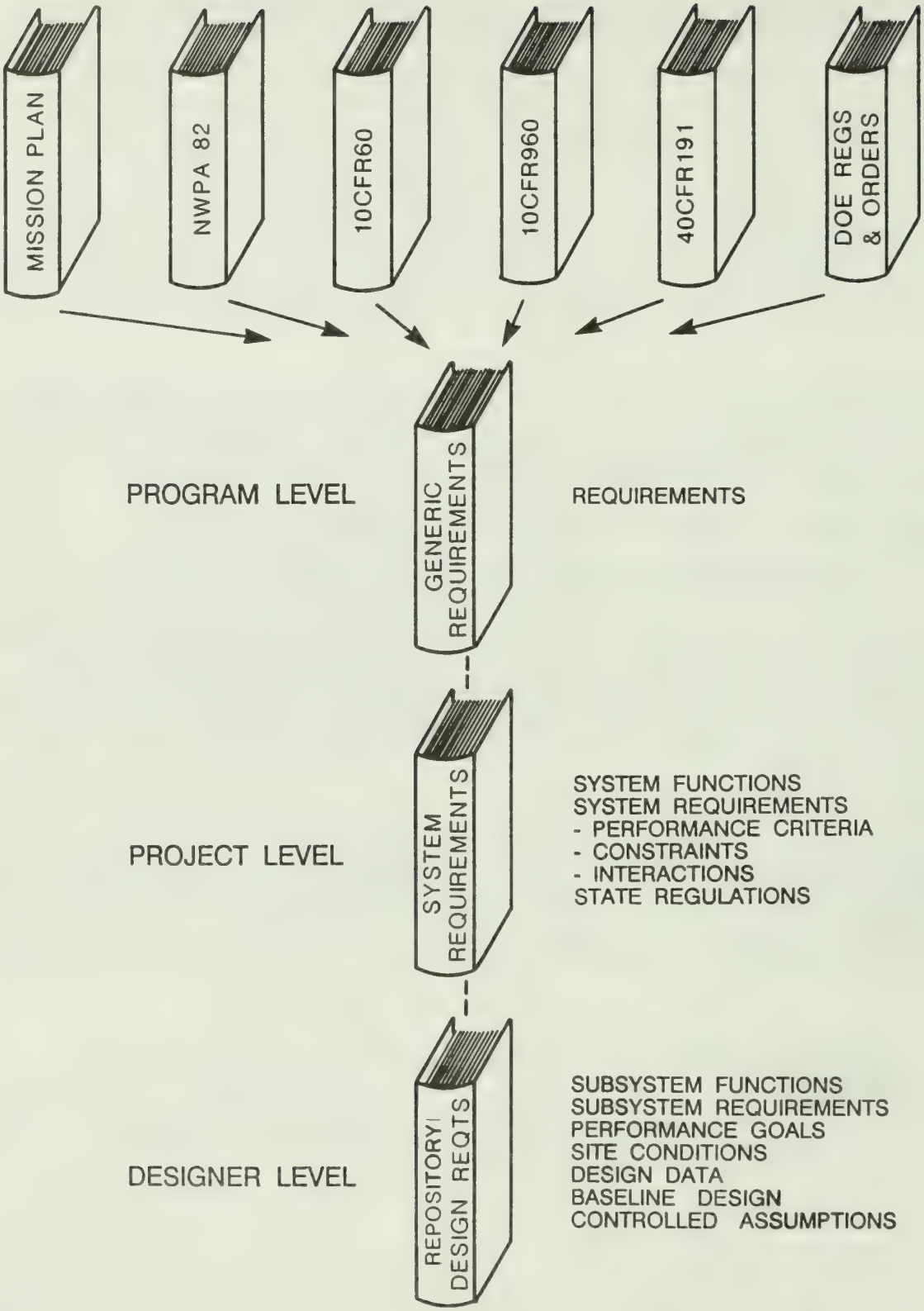


Figure 8.3.2.5-2. Hierarchical relationships of requirements documents.

4. DOE order examples include

   a. "General Design Criteria," DOE Orders 4700.1, 6430.1, and 4300.1B.

   b. "Environmental Protection, Safety, and Health Protection Standards," DOE Orders 5480.4, 5480.1B, and 5480.1A.

The State of Nevada regulations to be considered include

1. Water quality standards.
2. Air quality standards.
3. Safety standards.
4. Mining regulations.

The program and project guidance documents are

1. Generic requirements (DOE, 1986c).
2. System requirements (DOE, 1986f).

The site-specific information to be considered are

1. Reference information base data on site properties.

2. Performance goals from related issues.

3. Reference design configurations and baseline design information from Issue 1.11, (configuration of underground facilities, Section 8.3.2.2) and this issue.

Logic

The RDR document provides site-specific instructions (design criteria) that will be used to develop a mined geologic disposal system (repository), consistent with the requirements set forth in the system requirements and the generic requirements. The basis for the RDR is a statement of the functions that the repository systems must perform and a specific statement of the functional parameters that the repository must meet. The current RDR will be further developed during each succeeding design phase. A technical change control system will be an integral part of the RDR updating process and the RDR will aid in controlling the scope of each repository design phase. As the design progresses to increasing levels of detail and design decisions are baselined, the SDR will also progress in increasing level of detail.

The repository design criteria contained in the RDR are derived from numerous Federal-government-related sources (Figure 8.3.2.5-2). These sources include the Nuclear Waste Policy Act of 1982, the Code of Federal Regulations (CFR), and DOE orders. The CFR includes regulations developed by the NRC, DOT, Mine Safety and Health Administration (MSHA), and the EPA. Applicable State of Nevada regulations are also included. The RDR also includes requirements generated by determining the (physical) elements of the Yucca Mountain mined geologic disposal system, their functions, and their associated requirements. Subsystem functions and requirements have also been

identified to aid the designer, and are supplemented by the use of performance goals determined in issue resolution strategies being used in various design and performance issues. In addition, design basis assumptions (i.e., use of backfill, container content, and one- or two-stage construction) and baseline design information (number and location of shafts and ramps, and reference emplacement configuration) are also included as guidance to designers and to limit the scope of the design studies. Finally, reference site conditions and reference design data to be used by the designers are identified.

The RDR is organized according to the physical subsystem structure. Sixteen major sections and supporting appendices follow an introduction that provides insight into the regulatory background for the document and its organization. The content of the various sections is indicated in Table 8.3.2.5-14. Sections 5 through 11 directly follow the work breakdown structure used in the Yucca Mountain Project as the basis for planning work and monitoring costs.

Changes to the RDR will be evaluated and authorized through the use of a technical change control system. As each new phase of design is entered, a major revision of the RDR will be needed. These major revisions make up the planned design activities to be completed under this information need.

Table 8.3.2.5-14. Organization of repository design requirements

Section	Content
1	Introduction--regulatory background and document organization
2	Site
3	General design requirements
4	Waste descriptions
5	Surface systems and utility systems
6	Surface facilities
7	Shafts and ramps
8	Underground excavations
9	Underground service and utility systems
10	Seals

Table 8.3.2.5-14. Organization of repository design requirements (continued)

Section	Content
11	Exploratory shaft facility
12	Special equipment design
13	Operations and maintenance
14	Permanent closure
15	Performance confirmation
16	Retrievability
Appendices	

8.3.2.5.4.1 Design Activity 4.4.4.1: Repository design requirements (RDR) for license application design

Objectives

The objective of this activity is to develop the design requirements for the repository for use in the license application design (LAD).

Description

The update to the RDR covered in this activity will be published before the initiation of the LAD. It will contain substantially more detail regarding surface and underground waste handling operations, a single emplacement orientation, and the results of numerous design decisions documented during advanced conceptual design (ACD).

8.3.2.5.4.2 Application of results

The principal users of the repository design requirements (RDR) will be the designers responsible for developing reference designs for the repository and its seals. The specific issues and information needs that will use information from the RDR are as follows:

Issue or information need	Short title	SCP section
1.11	Configuration of underground facilities --postclosure	8.3.2.2
1.12	Seal characteristics	8.3.3.2
2.1	Public radiological exposures--normal conditions	8.3.5.3
2.3	Accidental radiological releases	8.3.5.5
2.4	Waste retrievability	8.3.5.2
2.7	Repository design criteria for radiological safety	8.3.2.3
4.2	Nonradiological health and safety	8.3.2.4
4.4.5	Reference preclosure repository design	8.3.2.5.5
4.4.6	Equipment development and demonstration	8.3.2.5.6
4.4.10	Technology for seals emplacement	8.3.2.5.10

8.3.2.5.5 Information Need 4.4.5: Reference preclosure repository design

At any specific time the reference preclosure design is the result of a progressive, iterative design process. This process will result in refinements in design configurations between now and the start of construction. The reference preclosure design is the current design that reflects the most current design criteria, results from completed studies, and the available site data. The currently identified designs that will be produced before license application, along with a brief description of their intent are described in the repository program overview (Section 8.3.2.1). The designs are briefly described in the following paragraphs.

The Site Characterization Plan-Conceptual Design Report (SCP-CDR) is the reference design of the repository at this time. It is based on the criteria, studies completed, and site information available before the start of exploratory shaft construction. This design is used as the basis for a preliminary assessment of design feasibility and includes a preliminary description of planned repository operations. A cost estimate and construction schedule has also been developed for this design.

The advanced conceptual design (ACD) will be an expansion and extension of the SCP-CDR. Expansion will primarily concentrate on those elements of the repository that are important to public and worker radiological safety. One of the main objectives will be to identify and define design concepts that will be carried forward into the license application phase. This design

will incorporate results from additional data, refined calculations, additional tradeoff studies, and updated criteria. Repository costs and construction schedules will be updated for this design. A detailed operations plan will be prepared for this design.

The license application design (LAD) will be used as the basis for the license application. It will be highly detailed for those items classed as being important to safety and waste isolation and will include all items of the repository. This design will be evaluated by detailed analysis and calculations based on the refined, expanded data base resulting from additional site characterization work performed in the exploratory shaft facility or obtained by other means such as exploratory borings.

The products of this information need will be the major design reports that detail the design. These reports will be supported by topical reports, tradeoff studies, analyses, and operational plans created in this or related information needs. Major design reports will also be supplemented by the continual use of configuration control. Configuration control will allow design changes to be continuously monitored and documented and will also provide reference information usable for design analyses needed for tradeoff and sensitivity studies. At any specific time, the reference configuration will appear in the reference information base (RIB). More and more detail will be controlled in the RIB as the design progresses toward the LAD configuration. The final procurement and construction design will be developed after submittal of the license application as the basis for repository construction, and will not be discussed here. This information need will provide the input to all analyses, calculations, and studies that are sensitive to the repository configuration and operational procedures. The reference design also provides the basis for repository construction and operational cost estimates and schedules.

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The current repository design is shown in Section 6.2. The basis for this design is provided in Section 6.1; site data supporting the current design are given in Chapters 1 through 5, and the waste package configuration is given in Chapter 7. Chapters 3, 4, and 5 of the SCP-CDR contain an expanded description of the repository design and planned operations.

Parameters

The site parameters needed to develop the reference preclosure design and to complete the studies identified in a subsequent paragraph under this information need are identified in other information needs. The major categories of parameters needed are (1) parameters related to waste quantities and characteristics, (2) mechanical properties of the disposal horizon, (3) thermal properties of the disposal horizon, and (4) the surface characteristics of the site.

Logic

The reference preclosure design is developed through an iterative process. It will become more complete and more detailed with each iteration as a result of the availability of more data and the completion of additional analyses. The number of design alternatives decreases with each design stage until, in the final design, the only alternatives still available are those contingent on anticipated variations of the geology. The analysis supporting the reference design becomes more definitive as the design progresses.

Numerous design activities are planned preceding and during advanced conceptual design. These activities include evaluations of the chosen design and tradeoff evaluations conducted to evaluate design options or alternatives. Some design activities will require site data and some will not. The currently planned design activities that require site data are detailed below; in addition, examples for those required activities that do not require site data are also given.

Supporting activities requiring site data

The following supporting activities require site data:

1. Repository orientation evaluation: An evaluation that assesses the design impact of the repository orientation relative to the in situ principal stresses, fracture and fault geometry, and stratigraphy.

2. Construction contingency plan: A plan for contending with local anomalies (such as bad ground) that may be encountered in the construction of the repository.

3. Underground facility boundary evaluation: An evaluation that will determine the boundary for the underground facilities.

4. Probable maximum flood determination: This determination will be used in conjunction with surface topography for designing flood protection barriers for the surface facilities and underground accesses and will be used in locating both the surface facilities and the entrances for the underground accesses.

5. Retrieval environment prediction: A prediction of the environment that may be encountered during retrieval as a function of the time after emplacement. Drift temperature will be predicted as well as drift condition for both normal and abnormal conditions.

6. Backfill evaluation: A topical report that examines the systems required to install backfill, the impact of the backfill installation operation on worker safety, and the expected properties of the installed backfill, and expected results on postclosure performance.

7. Analysis of the ventilation system: A comprehensive analysis of the ventilation system for the underground portion of the repository. This analysis will develop quantity requirements, pressure requirements, and flow velocities, and will also contain a cooling analysis to predict the times required for cooling to allow maintenance or

retrieval. The hardware and construction features will be identified and schematically designed as a part of this document. Radon gas and moisture loss or gain will also be addressed in this analysis. Similar analyses for establishing the filter configuration for the emplacement exhaust air are planned.

8. Underground seismic considerations: An evaluation of the effect of seismic events to determine the impact on the underground facility. Analysis will include ground support systems and emplacement boreholes as well as constructed features such as portals and shaft linings.

9. Surface seismic considerations: An evaluation of the effect of seismic events to determine the impact on surface facilities.

10. Foundations for surface facilities: A determination of the foundation requirements for surface facilities. Analysis will be made based on bearing capacity of soils, and building loads, including determinations of dynamic behavior of the foundation soil in order to include the soil-structure interaction effects due to seismic loads.

Supporting activities not requiring site data (given for example only)

The following types of supporting activities do not require site data:

1. Repository options evaluation: An evaluation to examine the impact of a single- or two-stage repository and fuel consolidation on repository cost, schedule, and function.

2. Operations plan: See Information Need 4.4.3 (plans for repository operations, Section 8.3.2.5.3) for a description of this ACD activity.

3. Electric design basis analysis: An analysis that quantifies the electricity requirements for the repository. The analysis will include the requirements for uninterrupted power, emergency power, and power for the experimental programs. The analysis will project power requirements through repository closure.

4. Surface facility criticality analysis: The waste preparation and storage areas of the surface facility will be analyzed to ensure there is no possibility for a criticality accident.

5. Water requirements evaluation: An evaluation to determine the quantity requirements for the fire, mining support, potable, and nonpotable water needed at the repository.

6. Waste transporter study: A comparative study of electric, diesel electric, and diesel locomotion for the waste transporter with emphasis on the impact of a decision on repository configuration, operations, cost, and safety and the effect of vehicle emissions on meeting performance objectives.

7. Hoist, headframe, and collar design alternatives evaluation: An evaluation that will result in the selection of the mine hoist type to be used at the repository.

Lists of supporting studies and trade-off evaluations will be developed before initiation of each design phase. These lists will be modified as needed during the design phase to reflect new design activities required as the design becomes progressively more detailed.

8.3.2.5.5.1 Application of results

The reference designs created in this information need will be used within this issue, as part of the basis for modifying the operations plan and for modifying the subsystems design requirements. The assessment that the repository can be constructed, operated, closed, and decommissioned using reasonably available technology will be made using the reference preclosure surface facilities, underground facilities, and designs for seals produced by this information need.

In addition to the above identified relationships within this issue, this information need will be used in the resolution of other issues and as input for other design information needs. Other issues and information needs are given in the following list. (Information Needs 2.7.4, 2.7.5, 2.7.6, and 2.7.7 are not covered in the SCP.)

Information need	Short title
1.11.3	Configuration of underground facilities (Section 8.3.2.2.3)
1.11.4	Design constraints to limit water usage (Section 8.3.2.2.4)
2.7.4	Means to limit worker internal and external radiation exposure, including ventilation, time, distance, and shielding
2.7.5	Means to monitor and control radiation exposure conditions, including means to respond to emergencies
2.7.6	Means to ensure nuclear criticality safety
2.7.7	Means to manage onsite generated radioactive waste and to decommission surface facilities

New information needs (design information needs from Key Issue 3) may be added as the scope of the environmental impact statement is developed. These design information needs, if any, may be expected to interact with this issue.

8.3.2.5.6 Information Need 4.4.6: Development and demonstration of required equipment

The repository system must be designed to accomplish four major tasks: (1) preparation of the waste for emplacement, (2) waste emplacement, (3) waste retrieval, and (4) closure. Each of these tasks relies heavily upon the use of equipment to accomplish the needed work. Most of the required equipment has been used previously for similar purposes; however, each task presents the potential need for equipment that is unique and unproven in similar applications or environments. It is these unproven items that will be the focus of proof-of-principle demonstrations planned before license application.

This information need is the focal point for the equipment development program needed in support of the development of a nuclear waste repository at Yucca Mountain. This information need will have four principal products:

1. List of equipment planned for use in the repository.
2. Designs for equipment that are unique to repository applications.
3. Equipment.
4. Demonstrations to establish capabilities of repository equipment.

Numerous supporting documents (development plans, test procedures, performance goals, design criteria, etc.) will also be created.

The products just identified will be used in a variety of ways, including as the bases for operations planning, as well as safety, cost, and feasibility analyses. Most of the equipment will require little information about the site and will, therefore, not be discussed in detail in this document. The repository design plan will contain substantially more information on the equipment development program needed for the repository. The principal focus of the remaining discussion in this section will be on the activities (and data needs) associated with the evaluation of the feasibility of drilling and lining of long, horizontal, waste emplacement holes.

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The operation descriptions for the repository are contained in Section 6.2.3 of this document. The equipment items requiring development and demonstration are included in these operational descriptions. Similar discussions are contained in Sections 3.1, 3.2, and 4.5 of the SCP-CDR (SNL, 1987). The equipment that does not require substantial site data will be described in the repository design plan.

Parameters

The parameters or information needed by the equipment development program are as follows:

1. Site parameters.

    a. Fracture characteristics of host rock.

b. Abrasiveness of host rock.

c. Rock-cutting characteristics, including dependence on in situ stresses.

d. Existence of free water in the rock mass.

e. Normal and abnormal conditions of drifts and borehole.

2. Other information needed:

a. Plans for repository operations (Information Need 4.4.3).

b. Repository design requirements (Information Need 4.4.4).

c. Design analyses (Information Need 4.4.7).

Logic

Independent of requirements for site data, development and demonstration of a typical piece of equipment generally consists of the following steps to be completed before the license application:

1. Development of reference equipment configurations. The development process will be recorded in topical reports that depict the equipment, present operational procedures, and specify structural and performance criteria.

2. Analysis of the reference designs for verification of functional adequacy, for compliance with the performance goals and for evaluation of necessity for proof-of-principle demonstration. This step will include the generation of separate topical reports for only the more significant analyses (e.g., operator dose).

3. Development of a test procedure for demonstration of the equipment. The emphasis of the procedure will be to identify the sequence of testing to be used to determine if the equipment will perform as required under the anticipated environments for both normal and credible abnormal conditions.

4. Fabrication of equipment, demonstration models, and test facilities as needed for proof-of-principle tests.

5. Demonstration of proof-of-principle.

6. Evaluation of demonstration results and modification of designs and criteria, as appropriate.

This sequence will be implemented for the development and demonstration of the unique, specialized equipment required for the repository. The development and proof-of-principle demonstration of the equipment should be completed before license application.

The Yucca Mountain mined geologic disposal system (MGDS) is introduced in Section 8.2.2. Examination of the subsystems and components of the MGDS will indicate that the preclosure subsystem relies heavily on equipment performing required functions. Subsystems currently being emphasized in the equipment program are highlighted here. The system elements and the equipment within these elements considered potential candidates for demonstration are as follows:

System element		Candidate for demonstration equipment
1.2.1	Mining	Equipment to mine the underground facility by use of mechanical miners
1.2.1.3	Borehole construction	For the horizontal emplacement option, the drill for drilling the long horizontal holes. For vertical emplacement, the drilling of vertical emplacement holes
1.2.2.1	Receiving	Remote systems for the removal of shipping cask restraints and cask closures
1.2.2.2	Preparation	Remote welding, inspection, and decontamination
1.2.2.4	Emplacement	Equipment to physically emplace the waste into vertical and horizontal waste disposal boreholes
1.2.2.5	Retrieval	Retrieval equipment for normal conditions and contingent or backup equipment for abnormal conditions, both vertical and horizontal emplacement options

More detail will be provided in the repository design plan regarding the types of equipment planned for use in each of these areas. Because only those items that require significant amounts of site data are considered in this document, the remainder of the discussion will focus on the equipment planned for use in borehole construction (System Element 1.2.1.3). Evaluations will also be made of the potential for using continuous miners and of the experience in using tunnel boring machines in similar types of rock.

A development prototype boring machine (DPBM) is currently being investigated. The DPBM is expected to be capable of drilling and installing a metal lining in long (up to 110 m) horizontal boreholes about 0.9 m in diameter. Demonstration tests for this DPBM are planned as part of the evaluation of the feasibility of horizontal emplacement of the wastes. The site data needed to support the development and demonstration of the DPBM are as follows:

1. Fracture characteristics of the rock. The fracture characteristics are an important part of the determination that the boreholes can be excavated and lined. The parameters needed to assess the fracture

characteristics of the rock are presented in Section 8.3.2.5.9, which addresses the feasibility of constructing the underground facility using reasonably available technology.

2. Abrasiveness of the rock. This parameter will affect the costs of the disposal boreholes. Highly abrasive rock will result in frequent cutter replacements and consequently it will affect the emplacement borehole costs. To obtain this parameter, it will be necessary to obtain rock samples for laboratory evaluation.

3. Tests in the exploratory shaft facility (ESF). The tests currently under consideration for the ESF involve the drilling of two 76.2-m-deep horizontal holes into the specific host rock and lining of these holes. The drilling of these holes will be highly instrumented so that data on drill performance can be obtained for use in predicting drill performance in the repository. These tests will also provide data for cost estimating. Other demonstrations may be planned to simulate the impact of potential abnormal underground conditions that may be encountered by other equipment. Definition of these tests awaits further definition of equipment and abnormal conditions.

8.3.2.5.6.1 Application of results

The equipment designs, the required performance, the lists of equipment planned for use in the repository, and the results of equipment demonstrations will be used for all the information needs of this issue. Site information requirements are passed to Information Need 4.4.1 (site and performance assessment information needed for design). Modification to the waste package design (particularly pintle interface requirements to be defined as part of Information Need 4.4.2) may depend on tradeoffs made in transporter designs. The types of equipment selected are input to the operations plan described in Section 8.3.2.5.3. Design requirements in Section 8.3.2.5.4, such as opening dimensions, may also change based upon the equipment designs; this would result in changes in the reference design described in Section 8.3.2.5.5. The equipment designs and the demonstration results will be important inputs to the assessments made in Information Needs 4.4.8, 4.4.9, and 4.4.10 regarding the use of reasonably available technology.

Other issues will also use the equipment designs and results from demonstrations. These include health and safety evaluations made in Information Need 2.2.1 and Issues 2.2, 2.3, 2.5, 2.6, and 2.7, as well as analyses in Issue 4.2 (Section 8.3.2.4) related to nonradiological concerns. Similarly, the evaluation of the feasibility of ensuring retrievability (Issue 2.4) will be based, in part, on the equipment demonstrations. Finally, cost estimates (Issue 4.5) for the repository will be dependent on the equipment selected for use and will be determined after scoping hearings for the environmental impact statement.

The short titles and Chapter 8 section numbers for the issues and information needs just discussed are as follows:

Issue or information need	Short title	SCP section
2.2	Worker radiological safety--normal conditions	8.3.5.4
2.2.1	Radiation environment	8.3.5.4.1
2.3	Accidental radiological releases	8.3.5.5
2.4	Waste retrievability	8.3.5.2
2.5	Higher level finding--preclosure radiological safety	8.3.5.6
2.6	Waste package characteristics (preclosure)	8.3.4.3
2.7	Repository design criteria for radiological safety	8.3.2.3
4.2	Nonradiological health and safety	8.3.2.4
4.4.1	Site and performance information needs for design	8.3.2.5.1
4.4.2	Waste package information needed for design	8.3.2.5.2
4.4.3	Plans for repository operation	8.3.2.5.3
4.4.4	Repository design requirements	8.3.2.5.4
4.4.5	Reference preclosure repository design	8.3.2.5.5
4.4.8	Technology for surface facilities	8.3.2.5.8
4.4.9	Technology for underground facilities	8.3.2.5.9
4.4.10	Technology for seals emplacement	8.3.2.5.10

8.3.2.5.7 Information Need 4.4.7: Design analyses, including those addressing impacts of surface conditions, rock characteristics, hydrology, and tectonic activity

Design analyses are important in comparing design options, determining the conditions under which the design meets the designated performance goals, and establishing credibility for the design approach being used. Site parameters, design requirements, and design configurations are required input for this information need. These inputs are used in numerous types of design analysis approaches for assessing the thermal, structural, hydrologic, and ventilation phenomena. This information need is the principal place where

rock mechanics analyses (including seismic effects) and ventilation calculations are discussed. Both normal and abnormal conditions are considered in the analysis of surface and underground effects.

The principal products or types of studies completed under this information need (Table 8.3.2.5-15) are design support studies such as tradeoff studies, sensitivity studies, reference calculations, and, where required, calculations to verify and validate the design approaches being used. The areas of analysis considered in this information need are shown in Table 8.3.2.5-15, which serves as the basis for the organization of the discussions presented in the logic section where the specific kinds of analyses to be done are identified.

The results of the design analyses completed under this information need will be used by the other information needs of this issue where the analysis will form the basis for needed modifications to the design or the design requirements and will provide the substantiation for the identified data needs. Compliance with retrievability requirements (Issue 2.4, Section 8.3.5.2), with requirements for nonradiological safety (Issue 4.2, Section 8.3.2.4) and comparisons of the analysis results with the goals established in Issues 2.4 and 4.2, will also rely heavily on (and will audit) the analysis performed here. Similarly, interfaces with goals from postclosure issues must be recognized. Examples of these interfaces are goals concerning waste package environment, the extent of the disturbed zone, and the areal power density.

This information need will be considered satisfied with the publication of the design analyses showing that performance goals and design criteria have been met.

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The design analyses described in this information need relate directly to other chapters of this document, particularly Chapter 6. The most substantial coverage of the current status of the analysis work is contained in Section 6.4.10. Numerous technical publications documenting the analyses completed to date are also referenced in this section of Chapter 6. The data used as the reference basis for most of the recent calculations is in Section 6.1 while the design that forms the basis for most of the calculations is given in Section 6.2.

The relationship between this information need and the SCP-Conceptual Design Report (SCP-CDR) (SNL, 1987) is similar to its relationship with Chapter 6. In the SCP-CDR, issue resolution status is provided in Chapter 8, and relationship to the NRC concerns is in Chapters 6 and 7. Chapter 2 of the SCP-CDR provides the basis for the current analysis while Chapters 3, 4, and 5 describe the current design.

Table 8.3.2.5-15. Preclosure design analyses

Areas of analysis[a]	Products or types of studies
UNDERGROUND	
Rock mechanics (thermal, structural, seismic)	Design support studies tradeoff studies
Ventilation Hydrologic Other	Sensitivity studies Reference calculations Verification and validation studies
SURFACE	
Rock mechanics	Design support studies tradeoff studies
Hydrologic Soil/mechanics/foundations Other	Sensitivity studies Reference calculations Verification and validation studies

[a]Each area includes, where appropriate, evaluations of normal and abnormal conditions.

Parameters

The parameters needed from site characterization to accomplish the analyses identified in the following logic section are summarized in the following list. The parameters are categorized and as follows:

1. General geometrical, soil, and rock parameters needed for surface facility design.
2. Rock parameters needed for subsurface design.
3. Hydrological parameters needed for surface and subsurface design.
4. Meteorological parameters.
5. Tectonic parameters.

General geometrical, soil, and rock parameters needed for surface facility design follow. The geometrical parameters are

1. Surface topography at facility locations.
2. Surface topography of access routes.

The soil parameters are

1. Alluvial stratigraphy.

2. Allowable foundation bearing load considering shear failure and total and differential settlement.

3. Soil structure interaction (if required).

4. Slope stability.

5. Time dependent settlement of earthfills and retaining structures if saturated clays are encountered (not likely).

6. Hydraulic related soil parameters.

The rock parameters are

1. Rock stratigraphy.

2. Allowable foundation bearing load considering shear failure and total and differential settlement.

3. Rock-structure interaction response (for soft rock with low shear wave velocity).

4. Slope stability.

The rock properties needed for the subsurface design for the linear elastic analysis of accessways and drifts are

1. Poisson's ratio.
2. In situ stresses.
3. Initial temperature.
4. Coefficient of thermal expansion.
5. Thermal conductivity.
6. Young's modulus.
7. Deformation modulus.
8. Joint cohesion and angle of friction.
9. Heat capacity.
10. Confined and unconfined compressive strength.
11. Cohesion of rock and angle of internal friction.

Additional rock parameters needed for incorporation of a rock joint model into analysis codes for the subsurface design are

1. Joint normal and shear stiffnesses properties.
2. Joint wall compressive strength.

3. Joint roughness coefficient.
4. Cohesion and coefficient of friction.

Additional parameters needed to use empirical methods for underground opening and ground support design are

1. Number of joint sets.
2. Frequency and spacing of joint sets.
3. Joint orientation.
4. Length of joint.
5. Rock quality designation.
6. Wall rock alteration.
7. Construction method.
8. Presence of squeezing or swelling ground.
9. Joint condition (roughness/free water/infilling).
10. Water inflow.
11. Expected seismic loading.

Other rock parameters are

1. Radon emission rate.
2. Abrasiveness of rock.
3. Porosity.
4. Saturation.
5. Permeability.
6. Radiation shielding characteristics.

The hydrological parameters needed for surface and subsurface design are

1. Subsurface.

    a. Estimate of water inflow into subsurface.

    b. Existence/location of perched water sources.

    c. Sustained yield of pumped water source for support of operations.

2. Surface (surface hydrology at surface facilities and access portals).

    a. 5-, 25-, 50-, 100-, and 500-yr floods.
    b. Probable maximum flood (PMF).
    c. Area of inundation.
    d. Flow velocities in areas in inundation.
    e. Debris load of flows.

The meteorological parameters are

1. Diurnal temperature and humidity of ambient air.
2. Seasonal temperature and humidity of ambient air.
3. Atmospheric dispersion.
4. Mixing height.
5. Average temperature.

6. Relative humidity.
7. Precipitation.
8. Wind speed.
9. Design wind load.
10. Design snow load.
11. Design value for precipitation.
12. Heating and cooling design values.

The tectonic parameters are

1. Surface fault displacement parameters.

    a. Identification and classification of late Quaternary faults within 100 m of facilities important to safety (FITS).

    b. Classification.

    c. Location at surface.

    d. Orientation at surface.

    e. Identification of any fault within 100 m of FITS with greater than 1 in 100 chance of producing more than 5 cm of surface offset in 100 yr.

    f. Integrated potential for fault displacement beneath FITS

    g. Probability vs. displacement relationship for area beneath FITS.

2. Underground fault displacement parameters.

    a. Identification and characterization of late Quaternary faults in the repository block:

        i. Classification.
        ii. Location at surface.
        iii. Orientation at surface.

    b. Identification and characterization of any faults within the waste emplacement area with greater than 1 in 10 chance of producing more than 7 cm of subsurface offset during the preclosure period.

    c. Integrated potential for fault displacement on faults that intersect underground facilities.

    d. Probability versus displacement relationship for the area of waste emplacement.

3. Surface vibratory ground-motion parameters.

    a. Design-basis ground-motion time histories (minimum bandwidth = 0.5 to 33 Hz) and corresponding response spectra (at 1 Hz intervals for surface FITS).

b. Integrated potential for vibratory ground motion at FITS.

c. Probability vs. peak acceleration, peak velocity, and peak velocity response at selected frequencies, at surface FITS.

4. Underground vibratory ground-motion parameters

a. Design-basis ground motion time histories and corresponding response spectra for underground facilities (at various depths) (minimum bandwidth = 0.5 to 33 Hz; 1 Hz intervals for response spectra).

b. Integrated potential for vibratory ground motion at underground facility locations.

c. Probability versus peak acceleration, peak velocity, and peak velocity response at selected frequencies, at underground facility locations.

5. Surface volcanic activity parameters.

a. Probability of volcanic eruption at location of surface FITS.

b. Design-basis ashfall thickness at sites of all surface facilities.

c. Ashfall particle density and size distribution.

6. Underground volcanic activity.

a. Probability of volcanic eruption through the area of waste emplacement.

b. Design-basis ashfall thickness (at surface vent intakes and exhausts).

c. Ashfall particle density and size distribution.

Logic

The analysis of the preclosure performance of the repository is an ongoing process. The process is progressively improved with each design iteration by the incorporation of new and better data and the use of improved analysis techniques. The current design of the repository is based on analysis techniques that may be improved as the design process evolves. The currently used methods of analysis are presented in this section for two reasons: (1) to illustrate the computer code types used for judging the applicability of the codes for repository design and (2) for the purpose of identifying the parameters needed to support the application of these computer codes. It is not anticipated that further improved codes or analyses techniques will require additional data beyond that identified in this section.

Only those analyses that require site data are presented. The analyses are categorized as (1) underground and (2) surface; under these categories the analyses are further divided into the basic types of analyses required. The rationale for reference calculations, sensitivity analysis, and computer code validation are also presented in the end of this logic subsection.

Analysis of underground repository facilities--structural-thermal analysis

The repository underground system elements that require structural analysis are 1.2.1.1, access construction (shafts and ramps); 1.2.1.2, drift construction; and 1.2.1.3, borehole construction. For some of these elements, (1.2.1.2 and 1.2.1.3) the structural analysis must be expanded to address the effects of the temperatures generated by heat from the waste. The potential long operational life of the repository dictates that the methods of analysis be adaptable for predicting the design adequacy for a long period of time.

System Element 1.2.1.1, Access construction (shafts and ramps)

Geomechanical analyses consider mechanical, thermal, and thermomechanical response of the rock mass through the emplacement and retrieval periods. The geomechanical goals indicate the need to understand the response of the host rock to excavation and thermally induced stresses. Excavation-induced stresses depend on the in situ stress field with superposed stresses derived from the size and geometry of the opening considered. Thermal stresses developed in the rock as a result of heating depend primarily on the magnitude of individual or combined heat sources, thermal properties of the rock, and the heat transfer mechanism; thus, these stresses vary with time and position. The effects of excavation-induced stresses are first evaluated and then the effects of thermal stresses are superposed on the former such that the thermomechanical response (the sum of the mechanical and thermal load components) also varies with time and position.

Our current understanding of the mechanical response of tuff is that the fractured rock mass can be treated as an elastic, elastic-plastic, or compliant-jointed media (Chapter 2 and Section 6.4.2). Current understandings of the mechanical response of fractured tuff have been based on and supplemented by three integrated sources of data: (1) field studies of the local and regional geology of the site (Chapter 1), (2) laboratory and field data indicative of the mechanical and thermal response of the rock from Yucca Mountain, and (3) data from in situ field experiments at Rainier Mesa and from laboratory experiments and rock samples from Rainier Mesa. The mechanical response predicted by a given analysis or set of analyses will depend on the scale, loading, and boundary conditions of the problem.

The approach to understanding and predicting mechanical response has been to use progressively more complex models through the course of design, performance, and safety analyses. For example, engineering judgment and practices are often applied at the onset to provide initial guidance to developing repository design. This judgment is qualified by data available before site characterization. The preliminary design warrants evaluation and confirmation through use of boundary element and finite element methods, and in situ test results. The predominant basis for planned license application analyses will be finite element methods.

The types of analytical tools being developed to provide a perspective of the rock mass mechanical response to address Issues 1.11 (configuration of underground facilities--postclosure, Section 8.3.2.2), 4.2 (nonradiological health and safety, Section 8.3.2.4), and this issue include the following:

1. Tunnel index methods (Barton et al., 1974a; Bieniawski, 1974), which are experience-based empirical methods that permit conclusions regarding ground support requirements and opening size. As yet, these methods do not account for the effects of heat.

2. Calculations using boundary element techniques will be used in preliminary evaluations of ground support requirements and will be compared with those determined by the tunnel indexing methods. The effects of excavation and heat may be included in the analysis. Rock strength, fracture slip, or both may be used to interpret results. These methods allow for parametric studies to be undertaken in which design tradeoffs can be evaluated through the predictions of deformations and stress at specific locations as a function of time. The usefulness of boundary element methods will be tested through comparison with closed form analytic solutions, finite-element codes, and underground exploration.

3. The predominant basis for planned license application analyses will be finite-element methods. Calculations using finite-element methods, treating the rock mass as an elastic, elastic-plastic, or compliant jointed media, will test the conclusions drawn from tunnel indexing and boundary element methods based on the effects of excavation and heat predicted throughout the area of interest as a function of time. These methods have the potential to consider rock strength, fracture slip, and fracture deformability as part of the computation, or these methods may be used to interpret results. Finite-element methods will be tested through comparison with closed-form analytic solutions, boundary element codes, underground exploration, and laboratory and field testing. The calculations using these methods will provide the final measure of the usability and performance of the designs.

Parameters necessary for the empirical structural design of the shafts and ramps. The design of the shaft and ramp cross-sections and the required ground support by use of a traditional, rock mass classification approach can be accomplished using a number of methods (e.g., Barton et al., 1974a (Norwegian Geotechnical Institute method) or Bieniawski, 1976 (Council for Scientific and Industrial Research method)). The method that will be used for the repository has not been selected. The parameters required for most empirical or experienced-based methods are specified in this section. Because the ramps and shafts pass through both the lithophysae-abundant and lithophysae-free parts of the Topopah Spring Member and the overlying members, parameters are required for both types of rock.

Parameters necessary for the analytical structural design of shafts and ramps. The accesses (shafts and ramps) must survive, in a usable condition, for a period of time equal to the retrievability period plus the time required for decommissioning. The time currently used to encompass the

retrieval period is 84 yr, and the estimated time for postretrieval decommissioning is 6 yr; therefore, the total time required is 90 yr. Postclosure aspects of repository design, including shafts and ramps, are discussed in Section 8.3.2.2.6.

Shafts and ramps will not be subjected to significant temperature changes during the repository operations. This is due to the distance between the shafts and ramps and the waste disposal area. The eventual temperature increase in the shafts and ramps is expected to be small and probably will not occur until they have been backfilled as planned by the seal program. Nonetheless, the analytical verification of the design of the shafts will consider the effects of thermally induced stress changes resulting from the adjacent waste disposal areas. This will allow an assessment of the effects of increased horizontal stresses and formation uplift due to thermal expansion.

The computer codes to be used for the initial structural design of the shafts and ramps will be selected from the list of codes provided in Section 6.4 (or similar codes will be used). Results of testing in the exploratory shaft facility will assess the suitability of these codes for design analyses supporting license application. The data or parameters required to apply these codes and to evaluate the potential for joint slip or excessive rock mass deformation are similar to the data that will be required for the codes selected for final design analysis. Two sets of parameters are required: (1) the parameters required when the rock mass is characterized as linearly elastic or elastic-plastic and (2) the additional parameters required to incorporate a description of the joints within the rock mass. These parameters are specified earlier in this section.

Two categories of parameters are needed: (1) those that can be measured directly or derived from measured values and (2) those that are subjective and must be determined by applying judgment factors. For the first category of parameters, the confidence with which the parameter needs to be determined depends on the sensitivity of the analysis method to the particular parameter as well as on the expected rock mass response. Preliminary sensitivity analyses indicate that the dominant parameters for assessing stability and in evaluating access opening shapes include (1) the unconfined compressive strength, (2) in situ stress, (3) the joint strength parameters, and (4) rock quality designation (RQD). Note that jointing at the site is predominately vertical based on current information; thus, the RQD determination may be biased. This bias will be examined through considerations of fracture spacings in three dimensions.

Parameters in the first category need to be determined by applying methods and selecting sample quantities that will give the required confidence in the resulting values. For the second category of parameters, only a medium confidence is required. These parameters must be obtained for all differing rock types encountered in the construction of the shafts and ramps. In using the compliant joint model, the significant parameters, in addition to those just listed, are the joint stiffness parameters.

System Element 1.2.1.2, Drift construction

The structural design of drifts differs from the design of accesses (shafts and ramps) in that the drifts may experience moderate temperature increases due to the heat output of the waste during the operational life. The effects of the increase in temperature on the design approach and the parameters needed are discussed in the following text.

Ground support design. The methods used and the parameters required for ground support design are the same as empirical and analytical methods described for the design of accesses. Support categories expected include rock bolts with wire mesh and localized shotcrete. In areas of poor rock quality, enhanced support may be required. These support systems are commonly used but they will require confirmation and careful material selection to ensure adequate performance during the retrievability period and compliance with postclosure requirements for chemical compatibility (Information Need 1.10.4, Section 8.3.4.2.4).

The planned approach to the design of the ground support for the repository may involve developing approximately four ground support designs. These designs could vary from simple rock bolts up to and perhaps including full concrete lining. Each design will be developed for a specific range of rock classifications. As varying rock conditions and types are encountered in the exploratory shaft facility (ESF), the preselected ground support may have to be varied. The support will be monitored for performance, providing an experience base that can be used in the repository. The ground support verification tests proposed for the ESF are described in Section 8.3.2.4.1.

The parameters needed to design the rock support system and to assess drift shape and size are the same as those listed for the access system element, but for the drifts, these parameters will be required only for the disposal horizon.

Long-term design considerations for drifts. The methods used to select drift size, shape, spacing, and support systems to accommodate long-term considerations are the same as for the access (shafts and ramps) except that now the effects of the heat generated from the decay of the waste must be incorporated. It will be determined if the heat effects can be simulated by the empirical methods such as those of the Norwegian Geotechnical Institute by increasing the stresses to account for the thermally induced stresses occurring after waste emplacement. Analytical techniques are available to explicitly model the temperature distribution around the drifts and calculate the thermally induced stresses. The support system designed and selected to accommodate the long-term considerations will be installed during construction.

The thermally induced stresses are expected to enhance stability in some areas and to destabilize other areas. If the degree of destabilization exceeds the capacity of the support system, then it will be necessary to enhance the support system or to reduce the temperature to decrease the thermal loads. Consideration of the thermally induced loadings requires additional thermal and thermomechanical parameters for the host rock and the support system. The thermally induced stresses depend on the temperature

distribution in the rock, which depends on the waste form and age, emplacement geometry, the areal power density of the emplaced waste ventilation conditions, and the rock thermal properties.

Currently the dominant heat transfer mechanism in the unsaturated tuff is understood to be temperature-dependent conduction. This understanding is based on laboratory and field tests and analyses (Section 2.5.3, relationship between intact rock and large-scale properties). The types of analytical tools being developed to provide perspectives of the rock mass thermal response include the following:

1. An analytic solution for heat conduction for finite cylinder heat sources with a decaying exponential source term with a time and linear superposition of sources. This analytical tool will serve the purpose of making preliminary design assessments for the repository.

2. An analytic solution for heat conduction for finite line heat sources that may be constant or exponentially decaying with time. This analytical method is an integral part of the boundary element method to be used to perform design and sensitivity analyses.

3. A numerical model capable of steady and transient linear and nonlinear thermal conduction analyses in at least two dimensions.

Possible boundary conditions include constant temperature at a node, constant or time-dependent temperature along the side, adiabatic surface, forced convection, natural convection, and thermal radiation. Material properties (densities, specific heats, and conductivity tensors) may depend on temperature. The method used will be tested using closed-form analytic solutions, benchmarking activities, and laboratory and field experiments. Heat transfer codes similar to the ones being considered have been successfully applied to analyses of heat transfer in salt (Waste Isolation Pilot Plant and Project Salt Vault), granite (Stripa), and tuff (Sections 2.5.2 and 2.5.3). The results of these analyses are used as input for thermomechanical analyses.

The current understanding of the combined contributions of the excavation and thermal effects upon rock-mass response is presented in Section 2.5. Based on this understanding, two methods are currently being applied to predict thermomechanical response. In the first, using boundary element techniques, thermal stresses and displacements are calculated by treating the thermal stress and the initial stress as a time varying boundary condition. In the second, using finite element techniques, mechanical responses from excavation and thermal responses from the heat source are separately analyzed and then the thermal results are input to the mechanical analysis to determine the thermomechanical response.

The temperatures will be estimated using a temperature-dependent heat conduction code similar to those used to predict temperatures in small-scale heater tests conducted in the G-Tunnel complex at the Nevada Test Site. These codes include SPECTROM-41, VISCOT, ADINAT, and COYOTE. The application of these codes requires the parameters, specified in Table 8.3.2.5-2.

Of the thermal properties needed, preliminary sensitivity analyses show the thermal coefficient of expansion has the most significant effect on the code outputs. The thermal coefficient of expansion is assumed to be isotropic, based on existing data presented in Chapter 2. Unlike mechanical properties, thermal properties are not expected to show any significant anisotropic effects as a result of joint sets (dominant or minor).

System Element 1.2.1.3, Borehole construction

The stability of the waste emplacement boreholes is important for maintaining the capability to retrieve the waste. Stability of the boreholes will be analyzed using the same methods and parameters as used for the analysis of the accesses and drifts.

Analysis of underground repository facilities--ventilation analysis

The repository underground system elements that require ventilation analysis are 1.2.1.6 (mining ventilation) and 1.2.2.7 (waste-handling ventilation). Analyses that have been used to this point in the design process are identified for the purposes of applicability assessment and to substantiate the parameters identified as necessary from site characterization. The design analysis techniques and codes may change for future designs; however, the data required to support the new analyses techniques is expected to remain the same as that identified here.

System Element 1.2.1.6, Mining ventilation

The current ventilation analyses use two computer codes. These codes are typical of codes used for mine ventilation analysis. The codes used are identified as VNET (ventilation network analysis) and CLIMSIM (climate simulation). They are used here only to substantiate the data needs specified and there is no intent to identify these as the codes that will be used for the license application analysis. In application, these codes are interdependent in that the results of CLIMSIM are input into VNET to determine ventilation system performance. CLIMSIM is used to model the psychrometric and environmental conditions in the airways. VNET is used to model the underground airflow distribution, calculate air-flow resistance, calculate friction pressure losses, and to establish ventilation fan requirements.

The information needed to apply these ventilation codes is identified in Section 8.3.2.5.7 and reiterated as follows:

1. Radon gas emission rates--the actual value of the emission rate is required. Also, it is important to know how the emission rate varies with rock type, natural and ventilation pressures, and location within the repository. Emission rates are needed to verify that the air quantities are sufficient to sweep areas of radon and to dilute concentrations to levels specified by regulations.

2. In situ moisture in the rock and the corresponding release rate to the ventilation airstream--required as a function of time, temperature, rock type, and location within the repository.

3. As-mined drift surface roughness--a determination of the roughness for each rock type, mining and support method used.

4. Potential for airborne respirable particulates--the particulate types and quantities are required.

5. Diurnal and seasonal barometric pressure, temperature, and humidity variations at the locations of the ventilation supply and exhaust portals.

6. Elevation of ventilation entrances and exhausts.

7. Surface rock wall temperature--the surface rock wall temperature in the unventilated drifts is required to perform cool down analysis. The surface rock wall temperature is calculated using computer codes such as SPECTROM-41 series, VISCOT, ADINAT, and COYOTE. The parameters needed to use these codes are given under the analysis requirements for System Element 1.2.1.2, Drift construction.

8. Heat transfer film coefficients for the rock walls--these coefficients will be derived from other parameters. The site parameter used in this determination is the surface roughness of the rock walls. This parameter has already been identified as necessary in other parameter lists.

System Element 1.2.2.7, Waste handling ventilation

The design and operation of the system required to provide ventilation to the underground areas where waste is handled is the same as that described under System Element 1.2.1.6 (mining ventilation). The site parameters required are the same as for System Element 1.2.1.5. Temperature increases in the rock are not considered during the emplacement activities but are of concern during waste retrieval and decommissioning.

Analysis of underground repository facilities--hydrologic analysis

The preclosure hydrologic analysis that will be required by the underground design will be the analysis to determine the potential for water in the emplacement boreholes. This analysis will provide a major input to the analysis for corrosion of the borehole components. The results of the hydrologic analysis will also be used for analysis of the environment in the emplacement borehole and for the analysis of the impact of formation water on the ventilation system.

Site parameters necessary to support hydrologic analysis are identified previously in this section.

Analysis of underground repository facilities--site seismic analysis

The seismic analysis of the underground facility can be done by several methods. The methods to be used for the repository have not been specifically identified. The methods used will probably be the same as those used for the design of surface facilities to resist earthquake loading. The parameters

necessary to apply the methods used are identified previously in this section.

Analysis of underground repository facilities--other underground analyses

There are other analyses that will be required for elements of the underground facility. Specifically, material compatibility analysis will be required for System Elements 1.2.2.4, emplacement, and 1.2.2.5, retrieval. The compatibility analysis will be done to ensure that the materials selected for the waste emplacement borehole liner will be compatible with the host rock and the waste package. The analysis required will principally involve corrosion analysis for determination of material corrosion and the determination of potential corrosion products. Chemical constituents of materials used in excavation or ground support will also be considered.

Analyses of repository surface elements

The information needed to develop the layout of the surface facility is identified previously in this section.

The structural analysis performed on the surface facilities will be based on currently accepted practices such as those recommended by the Uniform Building Code. Parameters necessary for the structural design of the surface facilities are identified previously in this section.

Types of analyses to be conducted

Table 8.3.2.5-16 lists some of the analyses to be conducted in support of the design. These analyses address the needs for reference calculations, sensitivity studies, tradeoff studies, and validation and verification of analytic techniques.

Rationale for reference calculations

Reference calculations are calculations whose results are incorporated in the reference information base (RIB). These calculations are based on current documented design geometries and configurations and use material properties data from the RIB. The purpose of reference calculations is to provide the DOE current referenceable design and performance analyses. Certain of the reference calculations may be used as input to other design or performance analyses, whereas others may serve as the basis for comparison in sensitivity analyses.

Reference calculations, as envisioned, will be performed for as many disciplines of the repository program as are necessary. Examples of these disciplines may include mechanical, thermal, thermomechanical, ventilation, seismic, and safety analyses.

Rationale for tradeoff studies

Tradeoff studies are studies in which elements or components of design are selected through choice comparisons. Tradeoff studies are typically done

Table 8.3.2.5-16. List of planned analyses

Analysis name[a]	Analysis objective	Analysis type[b]
DIM (H)	Selection of borehole spacing/length and waste standoff for horizontal emplacement	T
DIM(V)	Selection of borehole spacing/length/ waste standoff and drift spacing for vertical emplacement	T
DIM(E)	Selection of excavation geometry/ dimensions	T
BORE(V)	Vertical borehole analyses using elastic and inelastic codes	R
BORE(V,S)	Vertical borehole sensitivity analyses to variations in spacing and properties	S
BORE(H)	Horizontal borehole analyses using elastic and inelastic codes	R
BORE (H,S)	Horizontal borehole sensitivity analyses varying input properties	S
LINED	Horizontal borehole liner analyses including the structural interaction of the rock with liner (3-D effects)	R
LINED(S)	Horizontal borehole liner analyses including fault intersection, canister present	R
DRIFT(H)	Elastic and inelastic drift analyses for horizontal emplacement	R
DRIFT(V)	Elastic and inelastic drift analyses for vertical emplacement	R
DRIFT(S)	Drift sensitive studies for variation of input properties for horizontal emplacement	S

Table 8.3.2.5-16. List of planned analyses (continued)

Analysis name[a]	Analysis objective	Analysis type[b]
ANAL	Analyses on the effects of anomalies on the stability of drift and other excavations	S
VENT(V)	Time dependent heat flux and nonradial heat flow analyses for vertical emplacement	R
VENT(H)	Time dependent heat flux and nonradial heat flow analyses for horizontal emplacement	R
VENT(G)	Evaluation of radon and other gas dilution as well as moisture variations throughout the ventilation system	R
BOIL(H)	Analyses determine the time and extent of rock above boiling	R
BLAST	Structural effects of blast cooling both horizontal and vertical drifts	R
SEISMIC	Stability of underground excavations as effected by natural or induced tectonics	S
IN SITU TEMPERATURE	Determine the in situ temperature state as a function of position. Vary material properties, and boundary conditions to arrive at an applicable method which honors field data	R
ROCK MASS DEFORMABILITY PROPERTIES	Determine rock mass deformability properties for each thermal/mechanical unit using the compliant joint material model and laboratory and field data of intact rock and fractures	R

Table 8.3.2.5-16. List of planned analyses (continued)

Analysis name[a]	Analysis objective	Analysis type[b]
SMALL DIAMETER HEATER	Perform posttest thermal and mechanical analysis of the small diameter heater experiment from the G-Tunnel underground facility to evaluate rock mass response and thermal and mechanical analysis techniques	V
HEATED BLOCK	Perform posttest thermal and mechanical analysis of the heated block experiment from the G-Tunnel underground facility to evaluate rock-mass response and thermal and mechanical analysis techniques	V
ANISOTROPIC RESPONSE OF ROCK MASS	Perform a series of finite-element analyses to determine the relative effects of anisotropic material properties upon rock-mass response to in situ stress state, and supposed thermomechanical headings	S
ROCK MASS PROPERTIES	Performed analyses and update recommended rock-mass properties based on field and laboratory data	R
SLOT STRENGTH TEST	Perform pretest scoping analysis to support design of the slot strength test	S,V
SLOT STRENGTH TEST	Perform mechanical analysis of the slot strength test to evaluate rock-mass response and mechanical analysis techniques	V
SMALL DIAMETER HEATER	Perform thermal and thermomechanical analysis of the small-scale heater experiments to evaluate rock-mass response and thermal and thermo-mechanical analysis techniques	V

Table 8.3.2.5-16. List of planned analyses (continued)

Analysis name[a]	Analysis objective	Analysis type[b]
IN SITU MECHANICAL MODEL	Analyze the regional tectonics, stress measurements, and finite-element calculations at Yucca Mountain using the compliant joint model to provide an updated in situ mechanical model recommendation of Yucca Mountain for design analyses	R
FRACTURE CHARACTER-ISTICS	Update recommended fracture characteristics-based analysis of field and laboratory data	R
HEFF QUALIFICATION	Complete verification analyses for HEFF boundary element code	V
JAC VERIFICATION	Verify response of constitutive model components for the JAC compliant joint model	V
JEM VERIFICATION (SPECTROM)	Verify response of constitutive model components for the JEM compliant joint model	V
G-TUNNEL MINING EXPERIMENT	Perform post-test mechanical analysis of the G-Tunnel mining experiment from the G-Tunnel underground facility to evaluate rock-mass response and mechanical analysis techniques	V
BENCHMARK I	Perform benchmark calculations (code comparison) between compliant joint models to evaluate isothermal mechanical response at appropriate scales	V
LABORATORY LARGE BLOCK TEST-1	Perform pretest scoping analysis to support design of the large block laboratory test	S,V

Table 8.3.2.5-16. List of planned analyses (continued)

Analysis name[a]	Analysis objective	Analysis type[b]
LABORATORY LARGE BLOCK TEST-2	Perform analysis of large block test to continue validation procedure for compliant joint models	V
YUCCA MOUNTAIN HEATED BLOCK-1	Perform pretest scoping analysis to support design of the Yucca Mountain heated block experiment	S,V
YUCCA MOUNTAIN HEATED BLOCK-2	Perform thermal and thermo-mechanical analysis of the Yucca Mountain heated block experiment	V
SEQUENTIAL DRIFT MINING-1	Perform pretest scoping analysis to support design of the Yucca Mountain sequential drift mining experiment	S,V
SEQUENTIAL DRIFT MINING-2	Perform mechanical analysis of the sequential drift mining experiment to evaluate rock-mass response and mechanical analysis techniques	V
COMPLIANT JOINT BENCHMARK 2	Perform benchmark calculations (code comparison) between compliant joint models to evaluate mechanical and thermomechanical response at appropriate scales	V
G-TUNNEL SLOT TEST	Perform posttest mechanical analysis of the G-Tunnel slot test to evaluate and rock-mass response and mechanical analysis techniques	S,V
PLATE LOADING EXPERIMENT-1	Perform pretest scoping analysis to support design of the plate loading experiments	S,V
PLATE LOADING EXPERIMENT-2	Perform analysis of plate loading experiments to evaluate rock-mass response and mechanical analysis techniques	V

Table 8.3.2.5-16. List of planned analyses (continued)

Analysis name[a]	Analysis objective	Analysis type[b]
CANISTER SCALE HEATER EXPERIMENT-1	Perform pretest scoping analysis to support design of the canister scale heater experiment	S,V
CANISTER SCALE HEATER EXPERIMENT-2	Perform thermal and thermomechanical analysis of the canister scale heater experiments to evaluate rock-mass response and thermal and thermomechanical analysis techniques	V

[a]Analysis names: H = horizontal emplacement, V = vertical emplacement, S = sensitivity, B = borehole intersection, E = excavation, N = near-field, F = far-field, G = gases, R = radiological, NR = nonradiological, and A = accident.
[b]Analysis types: T = tradeoff study, S = sensitivity study, R = reference calculation, and V = verification or validation.

to select design options that will enhance functional capability and performance, increase safety of operation, will increase operational efficiency, or limit costs.

Rationale for sensitivity analysis

Sensitivity analysis will be done for numerous reasons, including

1. To determine the impact of the normally expected variations in parameters on the analyses and the design configurations.

2. To assign the quality requirements to the data needed (i.e., if the analyses using the data are only minimally or moderately sensitive to a parameter, then it will be sufficient to determine the parameter with a lesser degree of accuracy).

3. To determine the impact of design alternatives on repository function and costs.

4. To determine the impact of data variations on the ability of the repository design to meet the required performance goals.

The following studies are examples of sensitivity analyses:

1. A study to determine the effect of the length of the horizontal emplacement borehole on repository costs.

2. A study to assess the performance impact of the emplacement borehole orientation.

3. Analysis of alternative emplacement configurations, including short horizontal borehole concepts.

Rationale for validation of codes used for analysis

A generic discussion of verification and validation of models and codes identified for performance, safety, and design analysis is presented in Section 8.3.5.20. A brief discussion of the studies that have been conducted and that will be conducted in the site characterization program to test the models and codes needed for the analysis is given below.

Thermal Codes. Previous work and tests indicate that the ability to predict accurately the heat flow and temperatures developed from the emplacement of a decaying heat source in a geologic media is possible with the currently available codes, provided that the primary heat transfer mechanism is conduction. The previous work and tests include the following:

1. Climax--an experiment at the NTS performed in granite in which spent fuel was placed into boreholes drilled in the floor of a mined drift.

2. Project Salt Vault--an early experiment performed for salt in Lyons, Kansas. This experiment involved the placing of electrical heaters into salt. The temperatures in the salt surrounding the heaters was monitored and compared with predictions.

3. WIPP--extensive heat transfer experiments have been conducted in salt at the Waste Isolation Pilot Plant (WIPP) facility near Carlsbad, New Mexico. These experiments placed electrical heaters into holes bored into the salt. The temperatures developed in the salt are monitored and compared to temperatures predicted using predictive codes.

4. G-Tunnel--heat transfer experiments have been conducted at the G-Tunnel complex at the NTS. These experiments are conducted in volcanic tuffs.

Properties and characteristics of the Yucca Mountain site that will be used to evaluate the thermal codes will be obtained in laboratory tests (Section 8.3.1.15.1.1), from site heater tests (Section 8.3.1.15.1.6), and from the study of in situ temperature conditions.

Mechanical codes. As outlined previously, three levels of approach are to be applied to problems requiring mechanical analyses; these include the following:

1. Tunnel index methods--these methods have been proved for underground excavations without the addition of heat. Qualification of these

methods will include an incorporation of the thermally induced stress into support designs derived using these methods.

2. Boundary element methods--these methods have been recently applied to evaluations of underground stability. Within the limits of the intended applications of these methods, they require further qualification only through validation.

3. Finite-element methods--as currently developed, these methods allow for the most complex geometry, boundary conditions, and material behavior to be included in the analysis to evaluate underground stability. The current approaches to modeling rock-mass mechanical response include treating it as a linear elastic solid, as a continuum composed of intact rock and fractures, or, for applications near faults, as a continuum with discrete faults.

The mechanical response of the rock mass should be evaluated for ambient as well as increasing temperature conditions.

The measured mechanical response should be used to evaluate the applicability of the mechanical material models. For example, a linear elastic model may adequately represent the rock-mass response for certain load conditions. The constitutive description of the rock as a composition of linear elastic intact rock and nonlinear fractures should be evaluated as part of the qualification procedure. Each of the approaches will be carefully evaluated as regards applicability of the method and associated constitutive models; such evaluations will rely heavily upon actual observations during exploratory shaft facility construction and testing. Properties and characteristics of the host rock that will also be used to evaluate these codes will be obtained in studies in the laboratory (Section 8.3.1.15.1.3) and in situ (Sections 8.3.1.15.1.6, 8.3.1.15.1.7, and 8.3.1.4.3.2) and in design verification studies (Section 8.3.1.15.1.8). Thermomechanical codes will be evaluated against the results of the heater test (Section 8.3.1.15.1.6). The behavior of fractures will be modeled and the results will be evaluated in the laboratory studies (Section 8.3.1.15.1.3).

Seismic codes. Methodologies have been derived for predicting ground motion and seismic hazards (Vortman, 1986) based on limited field data. These methods require testing through the planned field program (Section 8.3.1.17.3.5).

Underground ventilation codes. The codes used for the design of the underground ventilation system should not require additional work for validation. This is because

1. These codes have been used for the design of numerous conventional mine ventilation systems and have successfully predicted the system performance.

2. The codes are based on older codes that have historically been successfully used for underground ventilation design. The codes used incorporate improvements to these older codes.

These codes will be evaluated in the in situ design verification study (Section 8.3.1.15.1.8).

8.3.2.5.7.1 Application of results

The results generated by this information need will be used within this issue for a variety of purposes. In Information Need 4.4.1 the results of sensitivity analyses will be used as input to determine what data are needed, as well as the level of confidence required for the data. Results are also needed to ensure design requirements (Information Need 4.4.4) are reasonable and that the equipment (Information Need 4.4.6) is being designed for an environment that is representative of what will be encountered in the repository. The results are extensively used for deciding if the design configurations (Information Need 4.4.5) need modification and for deciding that reasonably available technology can be used for the repository design, construction, operation, closure, and decommissioning (Information Needs 4.4.8, 4.4.9, and 4.4.10).

This information will also be used in numerous other issues (Table 8.3.2.5-17). In most of these other issues, the analysis results will be reviewed to ensure that performance goals related to these issues have been met. This is particularly true for Issue 2.4 (waste retrievability, Section 8.3.5.2) and for Issue 4.2 (nonradiological health and safety, Section 8.3.2.4), which stipulate goals or criteria related to the design analysis.

Table 8.3.2.5-17. Issues and programs that use design analyses results

Analysis area	Issues and programs using analysis results
UNDERGROUND	
Rock mechanics	1.1, 1.4, 1.10, 1.11, 1.12, 2.1, 2.4, 4.2, 8.3.1.15, 8.3.1.17
Ventilation	1.1, 2.2, 2.1, 2.4, 4.2, 8.3.1.15
Hydrologic	1.4, 1.12, 4.2, 8.3.1.16
Other (material compatibility)	1.1, 1.4, 1.11, 1.12, 2.4
SURFACE	
Rock mechanics	2.2, 2.3, 4.2, 8.3.1.14, 8.3.1.17
Hydrologic	2.2, 2.3, 4.2, 8.3.1.14

8.3.2.5.8 Information Need 4.4.8: Identification of technologies for surface facility construction, operation, closure, and decommissioning

This information need evaluates the effectiveness of those elements of the site that affect the design, construction, and operations of the repository facilities primarily during the preclosure period using reasonably available technology. If it is determined that any portion of the repository facilities cannot be built with reasonably available technology, then questions may be raised as to the feasibility of designing and constructing a repository facility that is safe and effective. In order to perform this evaluation, the characteristics of the waste and waste packages, surface conditions of the site, tectonic and igneous activities at the site, etc., must be understood because of their direct relationships to the design process and the operations of the repository. The evaluation of whether or not there is reasonably available technology will be based on potential of each associated system element to meet the performance goals for that element. The evaluation criteria to be used are as follows:

1. Determine that the proposed construction techniques have been used successfully in other applications or that there is no reason to believe that the techniques cannot be applied successfully at the repository.

2. Determine that design loadings and performance goals similar to those expected for the repository have been used for other surface facilities, including seismic loads, thermal loads, surface conditions, foundation conditions, flood and tornado type loads, and radiation containment, or that there is no reason to believe that they cannot be applied successfully at the repository.

3. Determine that operations similar to those needed to operate the repository have been performed successfully at other installations, or that there is no reason to believe that they cannot be applied successfully at the repository.

4. Determine that technology for constructing, predicting design and performance, and operating the repository can be demonstrated (by proof-of-principle demonstration, if appropriate) before license application to ensure its successful application in the repository.

The product of this information need will be evaluations that determine if the surface facilities can be constructed, operated, closed, and decommissioned using reasonably available technology.

Details of each of these evaluations along with their results will be provided in the different chapters of major design reports (e.g., advanced conceptual design report and licensing application design report). In addition, topical reports will be generated on some of the more important aspects (e.g., seismicity-tectonics and the associated design, flood control measures, foundation and structural design of waste handling buildings, and waste handling operations).

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

In this document, the use of reasonably available technology is reflected clearly in the performance goals described in the issue resolution strategy for this issue and is discussed in Section 6.4. Section 6.2 contains the current design and is the basis for statements made concerning technical feasibility.

Chapters 3, 4, and 5 of the SCP-CDR describe the current design, and Chapter 8 briefly discusses the use of reasonably available technology for the surface facilities.

Parameters

The determination that reasonably available technology is being used in the surface facilities relies heavily upon information produced by other information needs, including the following:

1. Reference designs for repository surface facilities.
2. Reference designs for waste containers.
3. Waste quantities and characteristics.
4. Repository operations plan.

In addition, a number of site parameters have been identified for input to the assessment of reasonably available technology. These parameters should be interpreted generally as being needed in the immediate vicinity of the surface facilities; they include the following:

1. Topographic characteristics of the surface facilities site.
2. Local meteorological conditions at the site.
3. Characteristics of the surface water systems at the site.
4. Flood recurrence intervals and levels at the site.
5. Location and characteristics of near-surface structural features of the site.
6. Location of adequate water supplies at the site.
7. Rates and magnitudes of igneous activity at the surface facilities.
8. Fault movements and tectonic activity at the surface facilities.
9. Ground motion at the surface facilities from man-made or natural seismic events.

10. Soil and bedrock properties at the surface facilities, static and dynamic moduli, bearing capacity, shear modulus and damping versus strain and depth from surface, shear wave velocity profile or a function of depth from surface, depth and extent of alluvium, settlement, etc.

11. Attenuation of ground motion with depth at the site.

Logic

The design of the surface facilities depends on site parameters. In particular, foundation design, flood protection system design, and evaluations of seismic effects on surface facilities require data. The data requirements for the design and supporting analyses are defined in Information Needs 4.4.5, and 4.4.7; data required for technical feasibility evaluations are generally limited to a need to confirm that the site data is not substantially outside the range currently being used for design. The logic used to identify the data needed is to determine the potential impact of being outside the current design basis values. This logic is displayed in the following:

1. If the underlying soil or rock conditions do not provide adequate strength to support the facility buildings or if they are susceptible to large settlements not acceptable for the repository buildings or operations, then construction or operation procedures may be more complicated than the currently accepted state-of-the-art techniques. Therefore, data are needed to confirm current design basis data that indicate that construction will be within state-of-the-art techniques.

2. Profiles of shear wave velocity, shear modulus, damping, and the extent of alluvium affect the soil-structure interaction on the loads on the structures due to earthquake loads. If these parameters are determined to be substantially beyond those used in the design, then modification of the existing analysis and design methodology may be required to produce designs that are capable of development with reasonably available technology.

3. Data on ground motion at the site from man-made or natural seismic events, significant surface fault rupture due to fault activities at the site, and effects of significant igneous activity at the site are needed to determine if current design basis expectations are acceptable.

4. Local meteorological conditions, topography and surface conditions, flood recurrence intervals and levels at the site, and characteristics of the upland drainage areas impact the flooding potential and may influence location of the surface facilities and the underground accesses. Technical data are needed to determine if the planned flood protection systems are feasible at the identified locations for the surface facilities.

Other items important in determining if reasonably available technology is being used will be described in the repository design plan. Only the site-related items have been described here.

The criteria identified in the introduction to this information need will be applied at each phase in the design to assess if reasonably available technology is being used. These evaluations will be documented in the major design reports (advanced conceptual design, licensing application design, and final procurement and construction design) and, where needed, in supporting topical reports.

Technical procedures to be used for characterizing the listed parameters should be consistent in level of Quality Assurance control with similar NRC Regulatory Guides and American Society for Testing and Materials Standards. Quality assurance requirements to be used will be consistent with the DOE Quality Assurance Program, as described in Section 8.6.

8.3.2.5.8.1 Application of results

The assessment that reasonably available technology is being used in the surface facilities will be used directly as part of the basis for satisfying this issue. The assessment will also be used outside this issue to increase confidence that performance goals for the repository will be met. For example, the safety analyses (Issues 2.1, 2.2, 2.3, and 2.7 in Sections 8.3.5.3., 8.3.5.4, 8.3.5.5, and 8.3.2.3, respectively) will benefit from the use of reasonably available technology since the data base for surface facility operations would be more credible. Nonradiological health and safety analyses (Issue 4.2, Section 8.3.2.4) will benefit similarly. The use of available technology will also lead to reduced uncertainty regarding the repository schedule and, hence, costs (Issue 4.5, Section 8.2.2.3.2.4).

8.3.2.5.9 Information Need 4.4.9: Identification of technologies for underground facility construction, operation, closure, and decommissioning

The use of available, proven technology in the underground facilities of the repository will provide assurance that the repository can be successfully constructed, operated, closed, and decommissioned.

The determination that reasonably available technology is being used will be based on the following criteria for the underground facility:

1. The proposed construction techniques have been successfully used in other applications under similar construction conditions or for which the results of any requisite development, demonstration, or confirmatory testing efforts before application will be available within the required time.

2. The techniques proposed for the construction of shafts, ramps, and underground openings have been successfully used in similar geologic and hydrologic conditions or for which the results of any requisite development, demonstration, or confirmatory testing efforts before application will be available within the required time.

3. The operations necessary to emplace, retrieve, and transport the waste have been based on operations that have been successfully demonstrated in other facilities or for which the results of any requisite development, demonstration, or confirmatory testing efforts before application will be available within the required time.

4. The items necessary for construction and waste handling that require development have been demonstrated before license application to ensure their successful performance in the repository.

The products of this information need, in aggregate, will constitute the assessment that determines that all aspects of the underground facility can be constructed, operated, closed, and decommissioned using reasonably available technology. This assessment will be included in a summary chapter of the documents that define the reference preclosure repository designs.

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

Chapter 6 of this document describes the current repository design in Section 6.2 and summarizes the status of this issue in Section 6.4.10. Chapter 2 contains the data base of geoengineering data used to support that design.

Chapters 3 through 5 of the SCP-CDR (SNL, 1987) describe the current repository design, while Chapter 8 summarizes the status of work toward this issue.

Parameters

The determination that reasonably available technology is being used relies heavily upon information developed in other information needs under this issue, including the following:

1. Repository operations plan.

2. Lists of equipment used in repository and anticipated equipment performance.

3. Design analyses.

The parameters needed for each of the applicable system elements for subsystem evaluations are listed as follows:

System Element 1.1.2, Subsurface

1. Host rock upper and lower contacts.
2. Location and properties of geologic structures.
3. Surface topography.
4. Site hydrology.
    a. Perched wat
    b. Flow-through structures.
5. Subsurface seismic characteristics.
    a. Peak acceleration.
    b. Peak particle velocity.
    c. Frequency spectrum.

System Element 1.2.1.1, Access construction (shafts and ramps)

1. Design analysis results on shaft and ramp stability (Information Need 4.4.7).
2. Rock characteristics (same as in Information Need 4.4.7).
3. Construction, demonstration, and monitoring results from exploratory shaft.

System Element 1.2.1.2, Drift Construction

1. Design analysis results on drift stability (Information Need 4.4.7).
2. Rock characteristics (same as in Information Need 4.4.7).
3. Construction, demonstration, monitoring results, and maintenance requirements from exploratory shaft facilities (ESF) including construction through structural features and lithophysae.

System Element 1.2.1.3, Borehole construction

1. Rock characteristics.
2. Consideration of results from any Development Prototype Boring Machine (DPBM) testing activities in G-Tunnel and ESF.
    a. Fracture characteristics of host rock.
    b. Abrasiveness of host rock.
    c. Rock-cutting characteristics, including dependence on in situ stresses.
    d. Existence of free water in the rock mass.

System Element 1.2.2.4, Emplacement

Equipment designs and demonstrations (see Information Need 4.4.6)

System Element 1.2.1.5, Water removal

Confirmation of design assumptions on limited available water quantities

System Element 1.2.2.5, Retrieval

See Issue 2.4 (waste retrievability, Section 8.3.5.2)

Logic

The parameters identified as required to evaluate the level of technology necessary for design, construct, and operate the repository will be used to develop the repository design and the design supporting analysis. These designs and associated analyses will be compiled in the milestone reports identified for this information need. The results of the design and analysis process will be judged according to the criteria specified to conclude that existing technology is sufficient.

The logic used to identify the site parameters needed for reasonably available technology assessments is to identify the relevant system elements, evaluate the operations within each identified element, and determine the site data needed to support the design (and demonstration) of the system element. Those underground system elements identified in the issue resolution strategy for this issue that must be evaluated to determine if advanced, untried technology is required to construct, operate, close, and decommission the underground portion of the repository are as follows:

System element	Name
1.1.2	Subsurface
1.2.1.1	Access construction
1.2.1.2	Drift construction
1.2.1.3	Borehole construction
1.2.1.4	Rock handling
1.2.1.5	Water removal
1.2.1.6	Mining ventilation
1.2.2.4	Emplacement
1.2.2.5	Retrieval
1.2.2.7	Waste ventilation
1.2.4.1	Underground closure

For each of the identified system elements, the explanation is provided below regarding the parameters needed to determine if reasonably available technology is being used. For numerous system elements, the same data are needed to establish technical feasibility as for design or analyses; hence, references to other information need discussions are common.

System Element 1.1.2, Subsurface

The ability of the subsurface to meet repository requirements without the need to use advanced, untried construction methods or operational procedures will depend on evaluations based on the following information:

1. Vertical location of the upper and lower contacts of the chosen repository formation at selected points within the potential repository area. This information will determine if the thickness of the acceptable host rock is adequate to support repository construction.

2. Location and geoengineering properties of geologic structures. The location of geologic structures will be used in the design of the subsurface facility; primarily, the information will be used to locate various parts of the underground facility and to determine the possible need for supplemental ground support.

3. Surface topography. The surface topography should be mapped to provide contours for the entire site area. This information will be used to establish overburden thicknesses.

4. Site hydrology. The existence of any overlying perched water reservoirs and aquifers must be determined. The existence of any underlying aquifers must be determined. These potential water sources must be evaluated in regard to their potential flow and hydraulic head potentials at the repository horizon. Flow through fractures or major geologic structures should be identified and quantified where possible.

5. Subsurface seismic characteristics. Values of the peak seismic accelerations, the peak particle velocity, and the frequency spectrum will be needed.

System Element 1.2.1.1, Access construction (shafts and ramps)

Note that the shafts and ramps, which provide the access to the underground, do not include any lateral development from the point of intersection with the repository horizon.

The conclusion that the shafts and ramps can be constructed using conventional techniques will be based on the design analysis and previous construction experience. If the analysis shows that the stresses are within the load carrying capabilities of the rock and that the selected support system and that other rock properties, such as fracture characteristics, are also amenable to conventional support systems, then it can be concluded that the construction can be done using existing technology.

The design process and analysis methods for the shafts and ramps are identified in Information Need 4.4.7. This information need also identifies the rock properties of the rock that are needed to perform the analysis.

System Element 1.2.1.2, Drift construction

The emplacement drifts are the elements of the repository where waste is emplaced. Access drifts are provided to connect the main haulageways with the emplacement drifts. A consequence of the waste emplacement in the drifts is an increase in the temperature of the rock. The maintenance of openings in a geologic media subjected to heating is uncommon; consequently, additional analysis beyond that required for the accesses (shafts and ramps) will be required to ensure that the openings can be maintained without the need for new, untried, or highly costly support systems. If the analyses show that the stresses induced by both excavation and waste-induced heating are within the load carrying capabilities of the rock and the selected support system and that other rock properties, such as fracture characteristics, are also amenable to support systems, then it can be concluded that the construction can be done using existing technology.

The analysis methods that are used to analyze the drifts for both the construction (preheated phase) and the operational phase where temperatures are increased are presented in Information Need 4.4.7. This information need also identifies the parameters needed to use these analysis methods.

The long-term stability of the drifts will be enhanced by a maintenance program that will ensure usability of the drifts to the extent required for inspection, maintenance, and retrieval. New or excessively costly ground support systems might be required if usability over the operational period is without the provision of a maintenance program. With a maintenance program the design of the long-term support systems is not expected to require new technology. In addition, construction demonstrations, monitoring results, and maintenance observations planned in the exploratory shaft facility will provide confirmation (or lack of) that the planned construction techniques can be used, even though structural features and in areas of relatively high lithophysae content.

System Element 1.2.1.3, Borehole construction

The borehole is defined here to include the actual hole bored into the host rock and the liner system that is installed into the bored hole to assist retrieval. The ability to construct the waste disposal boreholes and to design and install the borehole liner using reasonably available technology will depend on the same parameters identified for the development prototype boring machine demonstration testing discussed in Information Need 4.4.6.

System Element 1.2.1.4, Rock handling

Mining demonstrations conducted in the G-Tunnel complex at the Nevada Test Site indicate that rock fragmentation size produced by blasting is compatible with all commonly used rock handling systems. Based on these results, there is no need for additional site parameters or for advanced technology to design the repository rock handling system.

System Element 1.2.1.5, Water removal

The unlikely existence of large quantities of water in the mining horizon or in the strata penetrated by the accessways nevertheless could result in the need for high capacity water removal systems. Currently available information does not indicate the potential for water inflow sufficient to cause the need for advanced or unproven technology; thus, no specific parameter needs are identified except to indicate that confirmation is needed for design assumptions made regarding limited quantities of available water.

System Element 1.2.1.6, Mining ventilation

To determine if the ventilation of the mine (underground facility) will require systems that are beyond currently available technology, it will be necessary to analyze the ventilation based on the requirements for air quantity, quality, and cooling capacity. This determination will identify any area that might require ventilation flow quantities that necessitate excessive drift or shaft sizes, areas where the cooling requirement cannot be met with currently available hardware, and areas where condensate formation could occur and might hamper operations or present potential for spread of contamination. The analytical methods for the ventilation system and the parameters needed to apply these methods are identified in Information Need 4.4.7.

System Element 1.2.2.4, Emplacement

The capacity to emplace the waste into the disposal envelope using currently available technology depends on (1) the development and demonstration of the required equipment (Information Need 4.4.6), (2) the characteristics of the waste package (Information Need 4.4.2), and (3) the shielding characteristics of the host rock. Of these three items, only the shielding characteristics of the host rock require the acquisition of site data, and the data needed has been identified in Issue 2.7 (Section 8.3.2.3).

System Element 1.2.2.5, Retrieval

The ability to retrieve the emplaced waste using equipment and procedures that are within the capabilities of current, reasonably available technology will be evaluated in Issue 2.4. (Section 8.3.5.2); hence, no data needs are related to retrievability.

System Element 1.2.2.7, Waste handling ventilation

The design and operation of the system required to provide ventilation to the underground areas where waste is handled is the same as that described under System Element 1.2.1.6, mining ventilation. The parameters required are the same as for System Element 1.2.1.6. Temperature increases in the rock are not considered during the emplacement activities but are of concern during waste retrieval and decommissioning.

System Element 1.2.4.1, Underground closure

The operations required to close the underground portion of the repository are primarily based on current techniques and equipment. The potential

exception is backfilling. If backfilling is done during decommissioning, the following are of concern:

1. The required installed density for the backfill. If the densities are beyond the capabilities of existing equipment, a development program may be required. The need for high densities is not presently anticipated.

2. The amount of dust generated during backfilling and the water control requirements during backfilling. There is a potential for the generation of large quantities of dust during a backfilling operation. Coordination of dust suppression techniques with water control requirements will be required.

Other items important to determining if reasonably available technology is being used will be described in the repository design plan. Only the site related items have been described here.

The criteria identified in the introduction to this information need will be applied at each phase in the design to assess if reasonably available technology is being used. These evaluations will be documented in the major design reports (advanced conceptual design, licensing application design, and final procurement and construction design) and, where needed, in supporting topical reports.

8.3.2.5.9.1 Application of results

The assessment that reasonably available technology is being used in the underground facilities will be directly used as part of the basis for satisfying this issue. The assessment will also be used outside of this issue to increase the confidence that performance goals for the repository can be met. This assurance will lead to reduced uncertainty in the repository schedule and, hence, costs (Issue 4.5, Section 8.2.2.3.2.4). The use of available technology where possible will also have a positive impact on the retrievability issue (Issue 2.4, Section 8.3.5.2). Finally, higher-level findings associated with preclosure design, construction, operation, and closure (Issue 4.1, Section 8.3.5.7) will rely on results of this information need.

This usage of available technology will be coupled with planned demonstrations of retrieval capabilities to increase confidence that retrievability can be successfully accomplished. Similarly, higher confidence can be achieved in radiological and nonradiological health and safety predictions when the use of data from proven equipment concepts can form a principal part of the data base for the evaluations.

8.3.2.5.10 Information Need 4.4.10: Determination that the seals for shafts, drifts, and boreholes can be placed with reasonably available technology

This information need will determine if reasonably available technology is available for emplacing shaft, drift, and borehole seals. To determine if reasonably available technology is being used, repository and seal designs must be available along with the operations plan, the design criteria, and selected placement methods.

The product of this information need will be evaluations that determine if reasonably available technology is being used to emplace seals. Summaries of each evaluation will be provided in major design reports (e.g., advanced conceptual design, license application design, final procurement and construction design). In addition, topical reports may be generated on some of the more critical components.

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The technology used to emplace seals depends, to a large degree, on the design of the repository and the desired performance of seals. The design of the repository and current sealing concepts are presented in Section 6.2 of this document. The status of technology evaluations for seals is included in Section 6.4.

In the SCP conceptual design report (SCP-CDR) (SNL, 1987), the seal design concepts are given in Sections 5.2 and 5.3, and the repository design is described in Chapter 4.

Parameters

The parameters or information needed to determine if reasonably available technology can be used for emplacing seals are as follows:

1. Reference preclosure repository designs (Information Need 4.4.5).
2. Reference seal designs (Information Need 1.12.4, Section 8.3.3.2.4).
3. Placement methods (Information Need 1.12.3, Section 8.3.3.2.3).
4. Plans for repository operations (Information Need 4.4.3).
5. Repository design requirements (Information Need 4.4.4).
6. Equipment development and demonstration (Information Need 4.4.6).

Logic

Use of proven technology to emplace sealing components is an integral part of the strategy that has been adopted in the Yucca Mountain Project seal program. This strategy will provide greater assurance that the seals can be emplaced to specified design requirements. Further, the use of proven technology will lead to limited demonstration requirements, thereby limiting potential schedule constraints in being able to license the repository. Site parameters important to the sealing program are defined in Information Need 1.12.2, (seal materials, Section 8.3.3.2.2), and Information Need 1.12.3, (placement methods, Section 8.3.3.2.3) and are therefore not repeated here.

Determination that sealing components can be placed with proven technology will be made using the performance goals, design requirements, seal designs, equipment requirements, and the list of planned operations. If the design requirements cannot be readily met using available materials or emplacement technology, then multiple options to achieving performance goals will be investigated through the design process. For example, redundant seal designs, through multiple materials or over-designs, is one way that performance goals can be achieved. The materials testing portion of the Yucca Mountain Project seal program is currently investigating granular as well as the cementatious-based materials to give a greater flexibility in sealing the repository. If it is determined during design that other categories of seal materials are more effective in achieving sealing goals, these categories will be evaluated. Emplacement feasibility will be one major consideration in selecting the appropriate materials and designs.

At each phase in the design, the seal designs will be evaluated to assess if reasonably available technology is being used (planned) for seal emplacement. The evaluations will be documented in the major design reports (advanced conceptual design, license application design, and final procurement and construction design) and, where needed, in supporting topical reports.

8.3.2.5.10.1 Application of results

The assessment that seal emplacement can be accomplished using reasonably available technology will be directly used as part of the basis for satisfying this issue. It will also be used to establish a higher degree of confidence that many of the performance goals established in Issue 1.11, (configuration of underground facilities (postclosure), Section 8.3.2.2), can be met. These performance goals are in many instances related to interfaces established between sealing requirements and total system, waste package, and engineered barrier performance assessment needs.

8.3.2.5.11 Schedule for preclosure design and technical feasibility

Issue 4.4 (preclosure design and technical feasibility) includes 10 information needs. The schedule information for these information needs is summarized in Figure 8.3.2.5-3. This figure includes the information need number and a brief description, as well as major events associated with each information need. A major event, for purposes of these schedules, may represent the initiation or completion of an activity, completion or submittal of a report to the DOE, an important data feed, or a decision point. Solid lines on the schedule represent information need durations and dashed lines show interfaces among information needs as well as data transferred into or out of this design issue. The events shown on the schedule and their planned dates of completion are provided in Table 8.3.2.5-18.

The information need-level schedules, in combination with information provided in the logic diagram for this issue (Figure 8.3.2.5-1), are

DECEMBER 1988

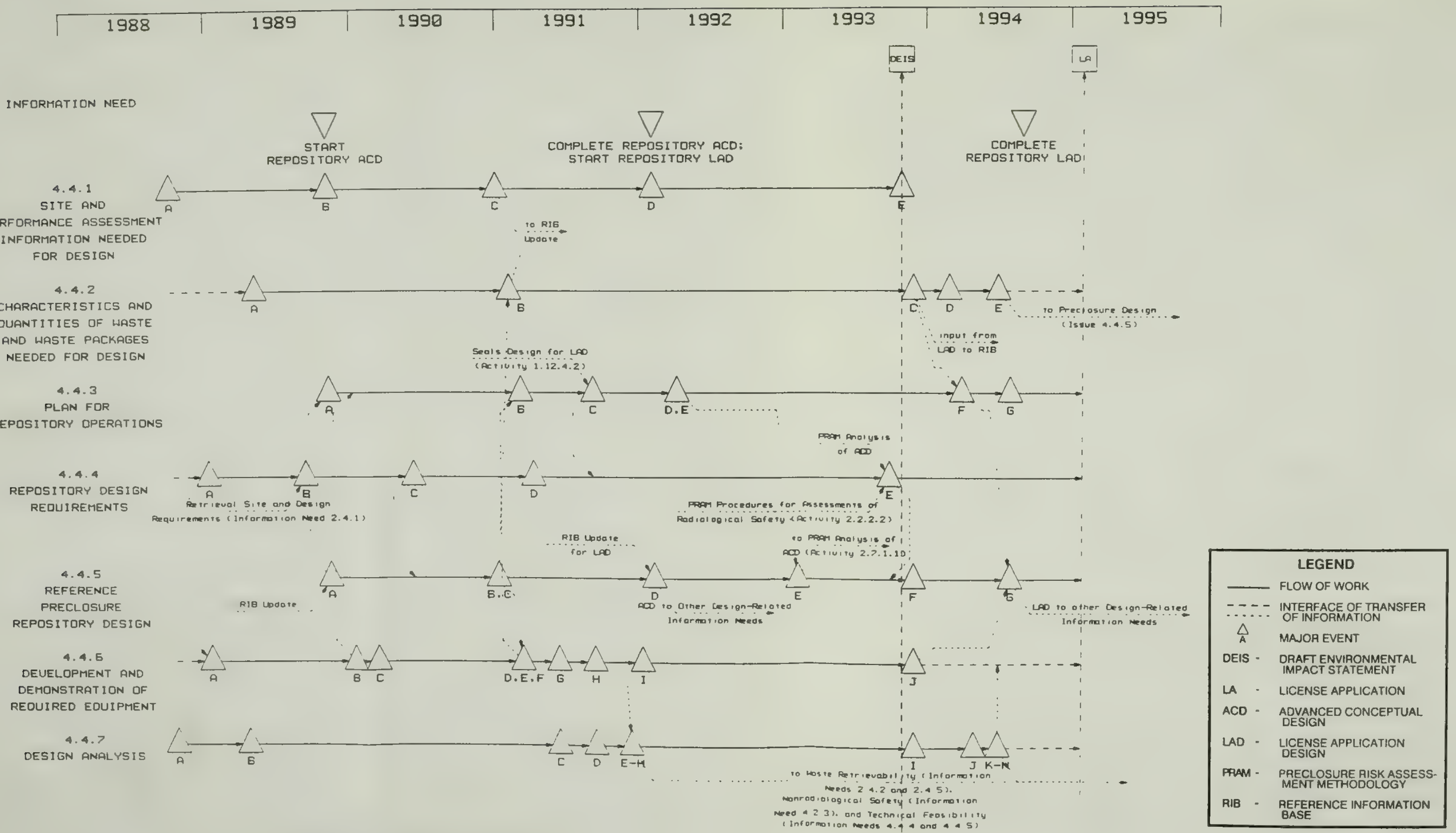


Figure 8.3.2.5-3. Schedule information for information needs in Issue 4.4 (preclosure design and technical feasibility) See Table 8.3.2.5-18 for descriptions of major events This network is consistent with the Draft Mission Plan Amendment (DOE 1988a) schedule Revisions will be published in semiannual site characterization progress reports as new information becomes available (page 1 of 2)

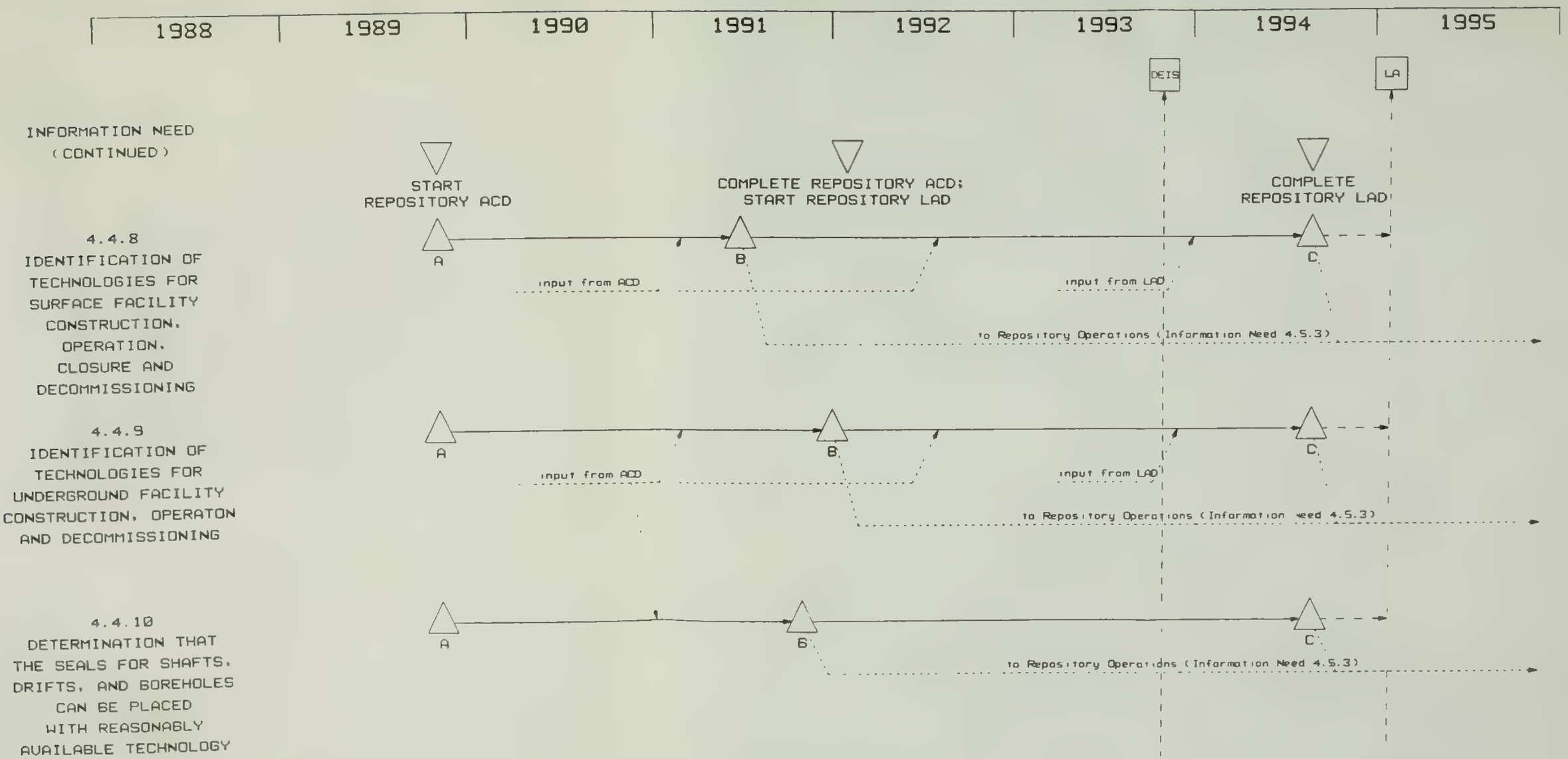


Figure 8.3.2.5-3. Schedule information for information needs in Issue 4.4 (preclosure design and technical feasibility). See Table 8.3.2.5-18 for descriptions of major events. This network is consistent with the Draft Mission Plan Amendment (DOE 1988a) schedule. Revisions will be published in semiannual site characterization progress reports as new information becomes available. (page 2 of 2)

Table 8.3.2.5-18. Major events and planned completion dates for information needs in Issue 4.4 (preclosure design and technical feasibility) (page 1 of 8)

Information need number	Brief description of information need activity	Major event[a]	Event description	Date
4.4.1	Site and performance assessment information needed for design	A	Continue updating repository design parameters needed from site performance assessment for advanced conceptual design (ACD)	10/88
		B	Evaluate existing repository design parameters (site data) and input to the reference information base (RIB)	10/89
		C	Complete updating repository design parameters (site data) for ACD freeze	12/90
		D	Complete updating of repository design parameters (site data) for start of license application design (LAD)	1/92
		E	Complete updating of repository design parameters (site data) for LAD	10/93
4.4.2	Characteristics and quantities of waste and waste packages needed for design	A	Waste package interface for ACD	4/89
		B	Waste package/repository design interface at ACD freeze	12/90

Table 8.3.2.5-18. Major events and planned completion dates for information needs in Issue 4.4 (preclosure design and technical feasibility) (page 2 of 8)

Information need number	Brief description of information need or activity	Major event[a]	Event description	Date
4.4.2	Characteristics and quantities of waste and waste packages needed for design (continued)	C	Waste package/repository design interface at LAD freeze	11/93
		D	Waste package/repository design interface at LAD complete	2/94
		E	Complete waste package/repository design interface documents for license application (LA)	6/94
4.4.3	Plan for repository operations	A	Start operations analysis for ACD report	10/89
		B	Start preparation of ACD operations plan report	2/91
		C	Complete preliminary repository operations analysis for ACD; start final ACD operations plan report	8/91
		D	Repository operations plan for ACD available for ACD report	3/92
		E	Start LAD operations analysis	3/92

Table 8.3.2.5-18. Major events and planned completion dates for information needs in Issue 4.4 (preclosure design and technical feasibility) (page 3 of 8)

Information need number	Brief description of information need or activity	Major event[a]	Event description	Date
4.4.3	Plan for repository operations (continued)	F	Complete repository operations analysis for LAD	3/94
		G	Repository operations plan for LAD available for LAD report	6/94
4.4.4	Repository design requirements	A	Reference repository design requirements (RDR) document available for start of ACD	12/88
		B	ACD RDR updated for ACD freeze	8/89
		C	Complete RDR for ACD	5/90
		D	Begin incorporation of RIB data to update RDR for LAD	3/91
		E	Update RDR for LAD freeze	9/93
4.4.5	Reference preclosure repository design	A	Start repository ACD	10/89
		B	Complete reference configuration of surface waste-handling facilities for ACD	12/90
		C	Repository ACD freeze	12/90

Table 8.3.2.5-18. Major events and planned completion dates for information needs in Issue 4.4 (preclosure design and technical feasibility) (page 4 of 8)

Information need number	Brief description of information need or activity	Major event[a]	Event description	Date
4.4.5	Reference preclosure repository design (continued)	D	Complete repository ACD; Start repository LAD	1/92
		E	Complete repository ACD report	1/93
		F	Repository LAD freeze	11/93
		G	Complete repository LAD	7/94
4.4.6	Development and demonstration of required equipment	A	Begin development of repository equipment list for emplacement and retrieval	12/88
		B	Complete design of waste emplacement envelopes	12/89
		C	Waste emplacement information available for incorporation into detailed design for emplacement/ retrieval items	2/90
		D	Complete detailed design for emplacement/retrieval items	2/91
		E	Complete detailed design of emplacement/retrieval system hardware	2/91
		F	Complete emplacement/retrieval equipment demonstration plan	2/91

Table 8.3.2.5-18. Major events and planned completion dates for information needs in Issue 4.4 (preclosure design and technical feasibility) (page 5 of 8)

Information need number	Brief description of information need or activity	Major event[a]	Event description	Date
4.4.6	Development and demonstration of required equipment (continued)	G	Complete fabrication of emplacement/ retrieval demonstration equipment	5/91
		H	Complete emplacement/retrieval demonstration facility	8/91
		I	Start conducting emplacment/ retrieval equipment demonstrations	12/91
		J	Complete documentation of emplacement/retrieval equipment demonstration results for LA	11/93
4.4.7	Design analyses	A	Begin modification of analysis codes and preliminary benchmarking	10/88
		B	Submit information on analysis codes and preliminary benchmarking to repository ACD; begin final benchmarking	3/89
		C	Complete planning analysis for ACD	5/91
		D	Complete design analyses of surface facilities for ACD	8/91
		E	Draft report available to the U.S. Department of Energy (DOE) on repository access analysis for ACD	11/91

Table 8.3.2.5-18. Major events and planned completion dates for information needs in Issue 4.4 (preclosure design and technical feasibility) (page 6 of 8)

Information need number	Brief description of information need or activity	Major event[a]	Event description	Date
4.4.7	Design analyses (continued)	F	Draft report available to DOE on repository opening analysis for ACD	11/91
		G	Draft report available to DOE on borehole analysis for ACD	11/91
		H	Draft report available to DOE on design analysis of underground mine ventilation for ACD	11/91
		I	Complete surface facility design analysis for LAD	11/93
		J	Begin preparation of update report on repository access analysis	5/94
		K	Complete verification and validation of design analysis codes	6/94
		L	Complete update of repository opening analysis	6/94
		M	Complete geomechanical methodology certification for borehole analysis	6/94
		N	Complete updated mine ventilation analysis	6/94

Table 8.3.2.5-18. Major events and planned completion dates for information needs in Issue 4.4 (preclosure design and technical feasibility) (page 7 of 8)

Information need number	Brief description of information need or activity	Major event[a]	Event description	Date
4.4.8	Identification of technologies for surface facility construction, operation, closure, and decommissioning	A	Begin evaluation of technology requirements for repository surface facilities for ACD	10/89
		B	Complete evaluation of reasonably available technology for repository surface facilities for ACD	6/91
		C	Report available to DOE on technology requirements for surface facilities for LAD	8/94
4.4.9	Identification of technologies for underground facility construction, operation, closure, and decommissioning	A	Begin evaluation of technology requirements for underground facilities for ACD	10/89
		B	Complete evaluation of reasonably available technology for underground facilities for ACD	12/91
		C	Report available to DOE on technology requirements for underground facilities for LAD	8/94
4.4.10	Determination that the seals for shafts, drifts, and boreholes can be placed with reasonably available technology	A	Begin evaluation of technology requirements for postclosure sealing design for ACD	10/89

Table 8.3.2.5-18. Major events and planned completion dates for information needs in Issue 4.4 (preclosure design and technical feasibility) (page 8 of 8)

Information need number	Brief description of information need or activity	Major event[a]	Event description	Date
4.4.10	Determination that the seals for shafts, drifts, and boreholes can be placed with reasonably available technology (continued)	B	Complete evaluation of reasonably available technology for post-closure sealing design for ACD	10/91
		C	Report available to DOE on technology requirements for sealing design for LAD	8/94

[a]The letters in this column key major events shown in Figure 8.3.2.5-3.

intended to provide the reader with a basic understanding of the relationships between major elements of the site, performance, and design programs. The information provided in Table 8.3.2.5-18 and Figure 8.3.2.5-3, however, should be viewed as a snapshot in time.

The overall program schedule presented here is consistent with the Draft Mission Plan Amendment (DOE, 1988a). The site characterization program will undergo a series of refinements following issuance of the statutory SCP. Refinements will consider factors both internal and external to the site characterization program, such as changes to the quality assurance program. Such refinements are to be considered in ongoing planning efforts, and changes that are implemented will be reflected in the semiannual progress reports. Summary schedule information for this and other repository design issues can be found in Sections 8.5.3 and 8.5.6.

Nuclear Waste Policy Act
(Section 113)

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.3, Seal Program

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.3 SEAL PROGRAM

This section describes the activities required to develop designs and demonstrate performance of seals to be placed in shafts, ramps, drifts, and boreholes. Section 8.3.3.1 provides an overview of the Yucca Mountain Project (formerly the Nevada Nuclear Waste Storage Investigations (NNWSI) Project) seal program and describes the technical approach of the development program. It is important for the reader to understand the planning basis for the seal program. Various aspects of the seal program are discussed in different places in this document (i.e., site hydrology in Chapter 3, seal concepts in Section 6.2, and seal analyses in Section 6.4). The following topics are discussed in more detail in the sections noted:

1. Seal environment--the anticipated environment used to ascertain the need for and performance of sealing components (Section 8.3.3.1.1).

2. Seal components testing--the laboratory and field testing currently planned in support of the seal program (Section 8.3.3.1.2).

3. Seal design--current designs and design concepts for seals (Section 8.3.3.1.3).

4. Seal modeling--modeling and code development for designing and assessing performance of seals (Section 8.3.3.1.4).

Section 8.3.3.2 (Issue 1.12, seal characteristics) describes the future work planned in support of the sealing program with emphasis upon those activities that use data from site characterization. The discussion includes a preliminary performance allocation for the sealing system as evidenced by the performance measures and goals established for the system and its components. In addition, the site characterization data (parameters) needed in support of the seal program are identified. The discussions of future activities are organized on the basis of four information needs that must be satisfied to resolve the seal characteristics issue.

While the specific wording of Issue 1.12 appears to address only shaft and borehole seals, a broader interpretation is adopted in Section 8.3.3.2. To provide a complete and unified discussion of the sealing system for the proposed Yucca Mountain mined geologic disposal system (MGDS), Issue 1.12 addresses all sealing components within the underground facility in addition to the seals for shafts, ramps, and boreholes.

The schedule information provided in this section includes the sequencing, interrelationships, and durations of the design activities and should be regarded as a snapshot in time. Section 8.5 presents the major milestones, decision points, and summary schedule information for the repository program.

Nuclear Waste Policy Act
(Section 113)



Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.3.1, Seal Overview

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.3.1 Overview of the seal program

The primary objective of the Yucca Mountain Project (formerly the Nevada Nuclear Waste Storage Investigations (NNWSI) Project) repository sealing program is to develop sealing designs that will act to ensure that water will not compromise the containment and isolation of radionuclides from the accessible environment.

Because of the timing of the activities, the seal program is somewhat different from other design-related activities. The repository surface facilities, the accesses, and portions of the underground facility will be constructed shortly after construction is authorized; the remainder of the underground facilities will be constructed and waste packages emplaced during repository operations. The seals, on the other hand, will not generally be installed until the repository is decommissioned. If conditions anticipated as a result of exploratory drilling are confirmed during excavation of the exploratory shaft, it will be unnecessary to install either permanent or temporary shaft or ramp seal components at the time of access construction. Additional conditions such as sheet flooding will be further analyzed during the design to confirm that operational seals are not required. The shaft liner can be removed to emplace seal components later. Several different liner removal techniques are discussed in Fernandez et al. (1988). Because the liner does not provide structural support for the formation, removal of the liner is not expected to cause significant additional stress redistribution or to significantly modify the permeability.

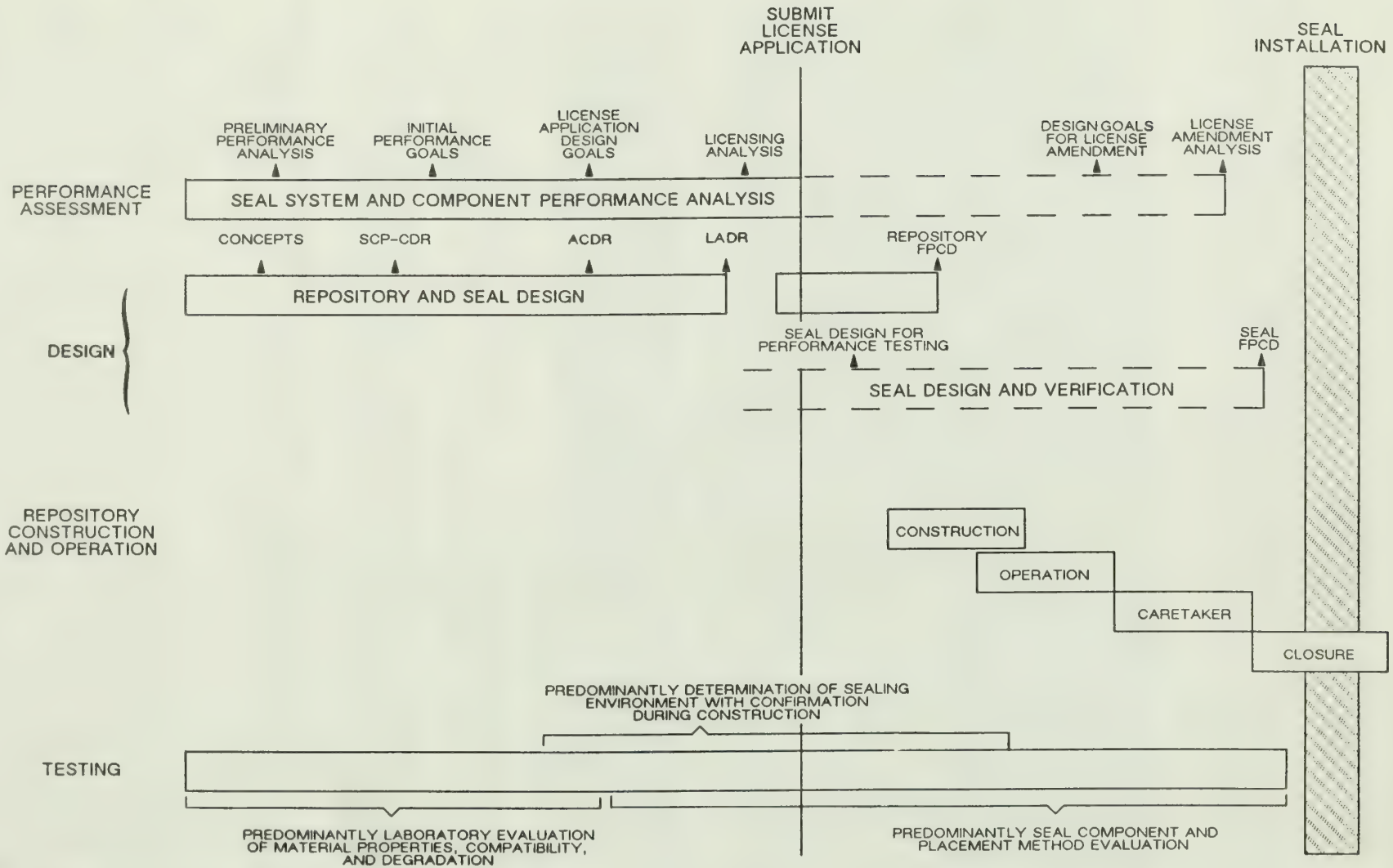
The sequencing of testing in support of the seal program also depends upon the planned timing for the installation of the seals. As noted in Figure 8.3.3.1-1, there is substantial time for testing of seal components after the initiation of repository construction. The timing is consistent with the NRC requirements (10 CFR Part 60, Subpart F) for the performance confirmation program, which note

1. It is anticipated that testing will be conducted "During early or developmental stages of construction..." (10 CFR 60.142(a)).

2. "Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts" (10 CFR 60.142(d)).

Both of these statements indicate that the sealing testing will continue after the license application, however, enough testing will be performed during site characterization to support the postclosure performance of sealing components.

The seal designs included in the license application design (LAD) may not be the designs used for actual construction of the seals since several (possibly as many as 50) years will pass before the seals are installed. During these years, many of the assumptions made in the development of the seal designs will be evaluated as data from access and underground facility construction becomes available. Similarly, data obtained from potential testing of seal components during repository operations will be available as a basis for design modifications. It is reasonable to expect that additional knowledge will be incorporated into the final design of the seals. The role



SCP - CDR - SITE CHARACTERIZATION PLAN - CONCEPTUAL DESIGN REPORT
ACDR - ADVANCED CONCEPTUAL DESIGN REPORT
LADR - LICENSE APPLICATION DESIGN REPORT
FPCD - FINAL PROCUREMENT & CONSTRUCTION DESIGN

Figure 8.3.3.1-1. Anticipated sequencing of sealing activities.

of the LAD for seal components is, therefore, to serve as the basis for analyses that will be included with the license application to establish the following:

1. The technology for constructing seals is reasonably available.

2. There is reasonable assurance that the seals have been designed so that, following permanent closure, they do not become pathways that compromise the geologic repository's ability to meet the postclosure performance objectives.

However, during the pre-license application period, several laboratory or bench-scale tests may be performed to increase the confidence that performance goals can be met. These pre-license application tests could include the following:

1. Laboratory or bench-scale testing to determine the rate of movement of fines into fractures as a function of flow volume.

2. Laboratory testing to determine index properties for the emplacement of grout and earthen or cementitious materials.

If the results of the laboratory test program indicate a potentially significant effect, then it may be necessary to perform a siltation-filtration test at the repository horizon with the addition of fines. The field test in which floor infiltration rates are made and compared with predicted flow rates through the use of fundamental constitutive relationships and modeling will serve to confirm the current understanding of infiltration rates at the repository horizon. If the results of laboratory testing indicate the need for removal of fines from the floor, then the effect of this treatment may also need to be investigated in the field test.

The post-license application tests may include small-scale in situ testing to examine specific design issues that evolve from the advanced conceptual design trade-off studies. The development for the need for specific sealing-related tests will continue during the advanced conceptual and license application design periods. During these periods, trade-off studies will be performed to give direction to the sealing design efforts and, subsequently, to the tests necessary to confirm performance or assumptions used in the design process. The entire seal design process, which culminates in the final procurement and construction design for the seals, will include the results of performance confirmation testing of seal components. This will include modification of sealing methods and concepts that might be necessary if the currently proposed sealing methods prove to be inadequate during performance confirmation testing. The discussions of the seal program in this document are structured around the efforts leading up to and required for the construction authorization application. The seal program includes the following activities:

1. Defining the sealing concepts.

2. Establishing performance goals and design requirements.

3. Developing the conceptual designs for sealing components.

4. Developing the license application design.

5. Establishing the properties of the sealing materials planned for use.

6. Evaluating the performance of sealing components at each stage in the design process.

8.3.3.1.1 Seal environment

The site hydrology is the dominant aspect of the environment for the seals. The current understanding of the site hydrology is described in Chapter 3. The partially saturated nature of the Topopah Spring Member in which the repository would be located, the anticipated relatively low water flux through the unit, and the potential for flow through discrete fractures or faults are important hydrologic aspects that require further evaluation. Other aspects of the seal environment that require consideration are related to surface rainfall and the potential for flooding, the stress and temperature fields to which the seals would be exposed, the bulk chemistry of the formation and the chemistry of the ground water, the potential for seismically induced forces or motion, and (principally for the borehole seals) the flow-related characteristics of the regions in the saturated zone below the repository.

Specific site information needed for the design and evaluation of the seals is identified in Section 8.3.3.2.1. Information such as the saturated hydraulic conductivity, gradational analyses, compressibility of shaft fill, borehole construction, and geologic logs associated with specific boreholes, will support the design process in the selection of the appropriate methods to emplace sealing components. Site information needed to validate analytical methods may include hydrologic characterization of the Topopah Spring Member (TSw2). Specific properties required are unsaturated matrix properties and the drainage capacity of the TSw2 unit. Prevalence of water-producing zones, if any, and the hydrologic nature of the Ghost Dance fault, the area underlying Drill Hole Wash, and the rock matrix will all be important site information needed to select the most appropriate sealing designs. The description of data needed in support of establishing or confirming the seal environment is based in part on the analysis work completed to date and the seal design concepts being used; these analyses and designs are summarized in Sections 6.4.3.2 and 6.2.8, respectively.

8.3.3.1.2 Seal components

In the Yucca Mountain mined geologic disposal system (MGDS), discussed in Section 8.2, the seals are identified as parts of two subsystems:

System Element	Description
2.2.3	Shaft and borehole seals subsystem
2.2.2.3	Repository seals and backfill subsystem (part of the repository engineered barriers)

A sealing component is a specific engineered structure that is part of one of these two system elements. The components (or sealing system elements) discussed below are based mostly on the work of Fernandez and Freshley (1984), which specifically addressed a repository located in the unsaturated portion of Yucca Mountain; the concepts of Fernandez and Freshley were modified during the development of the Site Characterization Plan-Conceptual Design Report (SCP-CDR) (SNL, 1987).

For a shaft, the components of the seals being considered are surface cover, shaft collar cores, anchor-to-bedrock plug and seal, settlement plugs, shaft fill, and the repository station seal (refer to Section 6.2.8 for further discussion of the components). For the Yucca Mountain site, ramps are planned (in addition to shafts) as a means of repository access. The seal components for the ramps are similar to those for the shafts. For the current concepts, the principal component of the seals for the boreholes is the seal in the portion of the borehole that penetrates the tuffaceous beds of Calico Hills; the remainder of the borehole may be filled with a granular material or a cementitious material as needed to control possible water inflow from the surface or gaseous movement of radionuclides from the repository. Decisions on which boreholes may need to be sealed will be made for each specific borehole with adequate consideration given to the effects of water and gas flow, including potential thermal effects resulting from the repository. Further discussion of the logic regarding which boreholes may need to be sealed (including location, depth, and distance from the site boundary) is provided in Fernandez et al. (1987) and in Section 8.3.3.2.

For the repository seals, the principal concern is related to options for sealing a discrete fault or fracture zone that may contain water. Options under consideration are discussed in Section 6.2.8.6 for a wide range of inflow. The determination of whether or not such inflow is credible at the Yucca Mountain site is one of the reasons for tests to be conducted in the exploratory shaft relative to structural features (Ghost Dance fault, Drill Hole Wash). Potential components for these options include excavation of a channel in a drift floor to constrain flow; small dams placed in drifts to impede lateral flow of water; and emplacement of physical barriers of bentonite, clay, or cementitious materials on each side of the flow to divert the flow downward and away from the waste packages.

The long-term compatibility of sealing components with their environment must be considered to ensure that long-term performance of the sealing components is acceptable. The testing program to provide data for assessing this compatibility is described in Section 8.3.3.2.2. These tests are intended to quantify the initial and (where possible) the altered physical, hydrologic, mechanical, and thermal properties of the seal materials.

Additionally, the chemical stability of the materials and their reactivity with the surrounding formation are being assessed for various components.

Currently in the Yucca Mountain Project sealing program, a broad range of sealing options and associated design requirements are proposed to provide assurance that performance goals can be met even if unanticipated conditions are encountered. Considering these sealing options and the associated design requirements, several material categories were recommended for future study. These categories are as follows:

1. Concrete.
2. Grout.
3. Crushed tuff.
4. Crushed tuff and clay.
5. Crushed tuff with fines removed.

The specific requirements or conditions considered in selecting these categories included hydraulic conductivity, strength or density, emplacement consideration, the potential adverse influences of seals on ground-water chemistry, and emplacement conditions. The current material preference in the Yucca Mountain Project sealing program is to use earthen materials, specifically crushed tuff, for as many applications as possible to minimize (1) potential degradation of physical properties and (2) potentially adverse effects on ground-water chemistry in the repository environment. In some locations cementitious materials may be more appropriate.

In 1987, the Stripa Task Force on Sealing Materials and Techniques conducted an overview and issued a state-of-the-art report on acceptability of different seal materials. The task force, composed of technical experts from the USA, Sweden, Canada, Switzerland, United Kingdom, Finland, and Japan, considered the following properties of prospective seal materials:

1. Permeability.

2. Thermal stability.

3. Emplaceability and resistance to fracturing.

4. Toxicity.

5. Avoidance of materials that might impair overall system performance, e.g., organic sealants.

6. Longevity.

After screening a multitude of material types, the task force concluded that cementitious materials and clay materials had a high probability of creating acceptable seals in virtually all repository environments (Coons et al., 1987). The bases for this conclusion include the low intrinsic permeabilities that can be achieved by clays and concretes, their thermal stability, their ease of emplacement, and their potential to perform satisfactorily overtime. These properties are discussed briefly in the following paragraphs.

Earthen materials (clays and crushed rock) can achieve hydraulic conductivities of less than 10^{-10} cm/s depending on the content of clays. For example, a value of 10^{-10} cm/s can be obtained from a mixture of crushed tuff with 30 percent Na-bentonite (Fernandez et al., 1987).

The range of typical concrete hydraulic conductivities is 10^{-8} to 10^{-6} cm/s while values of 10^{-10} cm/s have been achievable (Mathes, 1967). Values obtained by the Yucca Mountain sealing program for two grouts and one concrete ranged from 1.6×10^{-10} to 9.5×10^{-10} cm/s (Fernandez et al., 1987).

Low hydraulic conductivities have also been achieved by other programs for clay mixtures (Wheelright et al., 1981; Westik et al., 1983; Dixon and Gray, 1985) and cementitious mixtures (Gray, 1986; Hooton, 1986a,b).

Clays and portland cements have the ability to generate low permeability at the seal-rock interface and to heal or resist fracturing. In clay materials these properties are produced by the swelling of Na-montmorillonite (a mineral in bentonite) that occurs due to the uptake of water (Pusch, 1986). In portland cement these properties are generated by chemical reactions across the interface combined with high strength (Roy et. al., 1982), or by a very low ratio of water to cement (Gray, 1987).

Both clays and portland cements possess comparatively high thermal stability. Both materials are apparently stable at temperatures below 100°C and may perform acceptably to temperatures as high as 250°C (Koster van Groos, 1981; Scheetz and Roy, 1986).

Clay and cement are highly flexible in terms of environments where they may be emplaced. Either material can be used to fabricate an effective hydraulic barrier in boreholes, tunnels and shafts (Gulick, 1978; Pusch, et al., 1985; Ballivy, 1986; McCombie and Knecht, 1986; Pusch 1986).

Both clay and cement warrant the likelihood for longevity of performance. Clays are natural materials, such as crushed tuff, and reflect the stable products of chemical action on igneous and metamorphic rocks. Their stability in nature implies long-lived performance. Moreover, the alteration of Na-montmorillonite to other clays (e.g., illite), which could lead to decreased performance, is kinetically hindered to time periods in excess of hundreds of thousands of years if temperatures do not exceed 100°C (Eberl and Hower, 1976; Meyer and Howard, 1983). Some ancient portland cements have retained much of their structural integrity in both submerged and air-exposed environments for periods in the range of hundreds of years to a thousand years (Langton and Roy, 1983). Moreover, crystallization of amorphous CSH gel--the process that substantially leads to lost functionality in portland cement--is kinetically resisted at surface temperatures for periods of at least 3,000 yr (Hooton, 1986b). These factors combined with the low solubility of the materials and the potential to increase life by compositional adjustments (Grutzeck et al., 1980) leads to the inference of long-term stability.

8.3.3.1.3 Seal designs

The current designs for the seals are described in Section 6.2.8. More detail is provided in the SCP-CDR (SNL, 1987) and in the sealing concepts report (Fernandez and Freshley, 1984) published earlier. The technical basis for an initial set of design requirements and performance goals for the sealing components have been published (Fernandez et al., 1987). This technical basis consists of numerous evaluations of hydrologic conditions that exist at the site and that might exist in the future.

The advanced conceptual design and the license application design will be the next two phases in the design of seals. Trade-off studies will be performed to aid in the selection of appropriate configurations for seal components, selection of placement methods, and selection of the materials to be used. These trade-off studies will also allow refinement and reevaluation of the design requirements and performance goals. Several different types of design analyses have been identified in Section 8.3.3.2.4.2. These include analyses to evaluate the potential for drainage through drift floors, shafts, and ramps.

Additional evaluations to estimate the quantities of water that might enter shafts, ramps, and repository drifts from discrete faults and episodic flooding events are planned. The potential for flow through backfilled drifts will also be evaluated. These types of analyses will allow more definition of strategies for sealing discrete water-producing zones (if any are found), for dissipating water that might enter from extreme events, and for selecting materials to be proposed for use. Nearly all these analyses require site characteristics; the testing required to verify the conclusions reached in the preliminary studies will therefore be focused on confirming the site characteristics that are being (and have been) used as the basis for the design. As identified in Figure 8.3.3.1-1, the testing program for verification of the designs can then be developed in detail on the basis of the additional data collected for the site.

8.3.3.1.4 Seal modeling

Modeling seal performance is an integral part of the design activity for the seals. As indicated in the preceding section, modeling is used to establish the need for seals, the performance requirements, and the anticipated performance of the various components.

The logic for how seal performance is evaluated is given in Section 8.3.5.11, and the strategy for resolving the sealing issue is presented in Section 8.3.3.2. Models are needed for both saturated and partially saturated flow. Both numerical and analytical models have been used; the results published to date are described briefly in Section 6.4.3. The types of numerical and analytical approaches used to date are in Section 6.4.3.1. No new fluid-flow codes are expected to be required specifically for use in the seal program. Rather, codes that are being developed for use in other hydrologic performance analyses will be used for the seal program. Some potentially applicable computer codes, their capabilities, material models,

and the status of their documentation are described in Sections 8.3.5.19 and 8.3.5.20.

Nuclear Waste Policy Act
(Section 113)

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.3.2, Seal Characteristics

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.3.2 Issue resolution strategy for Issue 1.12: Have the characteristics and configurations of the shaft and borehole seals been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.134 and (b) provide information for the resolution of the performance issues?

This issue is concerned with developing seals needed for shafts, ramps, exploratory boreholes, and the underground facility. The regulatory basis for this issue, the strategy for resolving the issue, and the future work needed in support of developing and evaluating seal designs are described. The schedule information for the issue is given in Section 8.3.3.2.5.

While the specific wording of Issue 1.12 appears to address only shaft and borehole seals, a broader interpretation is adopted in Section 8.3.3.2. To provide a complete and unified discussion of the sealing system for the proposed Yucca Mountain mined geologic disposal system (MGDS), Issue 1.12 addresses all sealing components within the underground facility in addition to the seals for shafts, ramps, and boreholes.

Regulatory basis for the issue

There are several sections in 10 CFR Part 60 that relate to sealing, specifically 60.134(a) and (b), 60.112, 60.113(a), and 60.142(a), (b), (c), and (d).

Section 60.134 of 10 CFR Part 60, "Design of seals for shafts and boreholes," states

> (a) General design criterion. Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives for the period following permanent closure.
>
> (b) Selection of materials and placement methods. Materials and placement methods for seals shall be selected to reduce, to the extent practicable: (1) the potential for creating a preferential pathway for ground water to contact the waste packages; or (2) radionuclide migration through existing pathways.

These requirements specify the design criteria to be addressed by this issue. Provision (a) above also specifies the performance objectives in paragraphs 111-113 of 10 CFR Part 60. 10 CFR 60.111 refers to the performance of the geologic repository operations area through permanent closure, in particular, it refers protection against radiation exposures and releases of radioactive material before permanent closure and the retrievability of the waste (10 CFR 60.111). The seals systems may play a role in meeting this performance objective. This role is addressed by the preclosure performance and design issues, in particular, Issues 2.1, 2.2, 2.3, and 2.7. The reader is therefore referred to those sections of the SCP (8.3.5.3, 8.3.5.4, 8.3.5.5 and 8.3.2.3, respectively) for these issues.

Section 60.112 of 10 CFR Part 60 spells out the performance objective for the overall system performance for the geologic repository after permanent closure. The section states

> The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the U.S. Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

The NRC defines the engineered barrier system as the waste packages and the underground facility, and the underground facility as the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals.

Section 60.113 of 10 CFR Part 60, "Performance of particular barriers after permanent closure," which specifies the following requirements for the engineered barrier system:

> (a) General provisions. (1) Engineered barrier system. (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times . . . (ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that: (A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in 60.113(b) provided that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and (B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

Section 60.142 of 10 CFR Part 60 addresses the design testing associated with confirming performance of backfill and shaft and borehole seals. This section is as follows.

> (a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.
>
> (b) The testing shall be initiated as early as is practicable.
>
> (c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.
>
> (d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts.

To provide a complete and unified discussion of the sealing system, this issue (1.12) addresses seals related to shafts and boreholes as well as all sealing components within the underground facility and ramps.

Approach to resolving the issue

The approach to be used to resolve Issue 1.12 consists of a methodology for developing a seal system design that ensures compliance with the regulatory requirements. The methodology, when fully executed, provides the needed information at appropriate times to complete the design process for license application by demonstrating that Issue 1.12 is resolved.

The methodology for the resolution of Issue 1.12 is illustrated in Figure 8.3.3.2-1a and 8.3.3.2-1b and includes the following (steps are identified and discussed in the following paragraphs):

1. Issue identification (Step A). Includes (a) specifying the applicable regulatory requirements and (b) developing a system description.

2. Performance allocation (Steps B to F).

3. Testing.

4. Design and performance analyses.

This process is iterative, that is, as information is obtained, the design can be refined and the strategy can be suitably modified. Additional testing can then be conducted until the desired degree of confidence is obtained that the regulatory requirements are met.

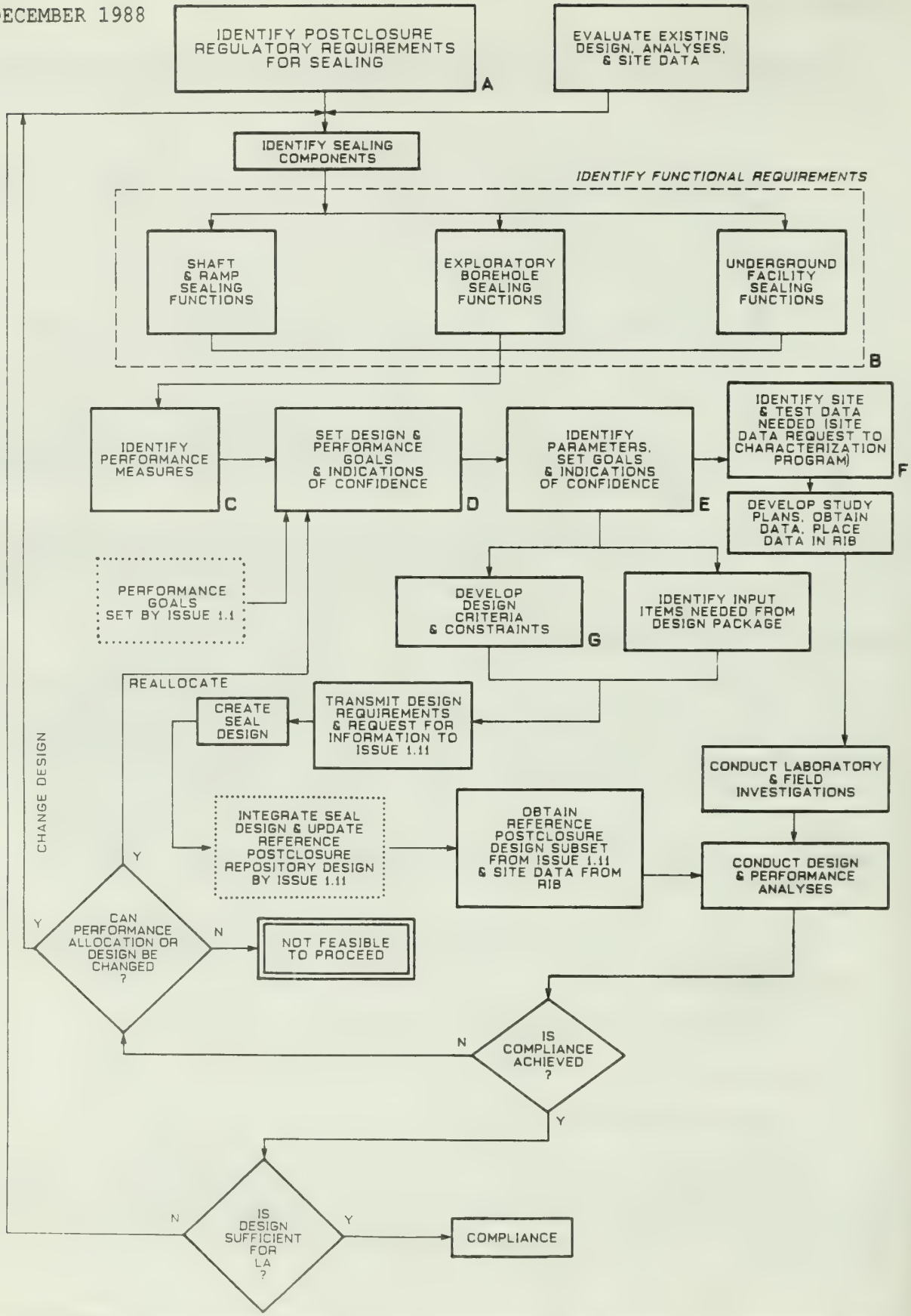
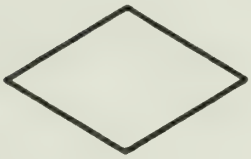


Figure 8.3.3.2-1a. Logic diagram for issue 1.12 (seal characteristics). See Figure 8.3.3.2-1b for legend Section 8.3.2.1 describes the relationships and interfaces between design and performance issues.

LEGEND



ACTIVITY PERFORMED TO RESOLVE ISSUE



TEST TO DETERMINE SUBSEQUENT ACTIVITY



ACTIVITY PERFORMED BY INDICATED ISSUE



ACTIVITY WITH MULTIPLE SIMILAR ACTIVITIES OR TESTS



DECISION ABOUT ISSUE RESOLUTION

Y - YES
N - NO
LA - LICENSE APPLICATION
RIB - REFERENCE INFORMATION BASE

Figure 8.3.3.2-1b. Legend for Figure 8.3.3.2-1a.

In applying the iterative methodology illustrated in Figure 8.3.3.2-1 to obtain a final design, it is important to consider the interface occurring between Issue 1.11 and Issue 1.12. This interface involves the transfer of sealing-related requirements, constraints, and information to Issue 1.11. It is then in Issue 1.11 that the sealing designs are integrated with other postclosure designs. The integrated reference postclosure design together with selected site and test data from the reference information base (RIB) is used to determine if Issue 1.12 is resolved.

The approach to be applied is indicated in Figure 8.3.3.2-1a. The process related to this issue (issue identification in step A and performance allocation in steps B through F) is briefly summarized in the following table:

Step	Summary
A	Use the regulatory requirements and the existing design, analyses, and site data, to identify the sealing components that make up the sealing subsystem.
B	Define the functional requirements for the seals (i.e., the function that each selected sealing component is to perform and the process that must be considered in assessing its ability to perform its function).
C	Identify the performance measures that can be used to show how well the sealing components perform their intended function.
D	Establish the tentative goals for the performance measures and the confidences needed in reaching the performance measure goals.
E	Define the parameters, establish tentative parameter goals, and estimate the level of needed and current confidence in meeting the parameter goals.
F	Identify information needed to resolve this issue. The identified information will be obtained as part of the activities that will satisfy various information needs including those under this issue, as well as under some other issues, particularly Issue 1.11 (Section 8.3.2.2, configuration of underground facilities--postclosure).
G	Develop the design requirements that apply to sealing options and identify the design constraints that are imposed on nonsealing system elements from the sealing system.

After these steps are completed, the Project will conduct laboratory and field investigations to obtain needed information. These investigations will feed design and performance assessment analyses.

Understanding each of these steps is essential for understanding how the information needs, which when satisfied by obtaining the data, will be used to resolve this issue. A more detailed description of steps A through G follows. Other descriptions relevant to these steps are described in other sections of the SCP.

Step A: Identify sealing system components

The tentative sealing component identified in Sections 6.2.7 and 6.2.8 were originally described in Fernandez and Freshley (1984) and consist of components associated with shafts, ramps, the underground facility, and boreholes. Figure 8.3.3.2-2 indicates the system elements that make up the sealing subsystem as discussed here, the potential locations of seals, and the sealing components being considered for each potential location. These sealing components are also identified in Table 8.3.3.2-1, together with their associated functions, processes, material properties, performance measures, and tentative goals. Sealing-related repository design constraints and goals are identified in Table 8.3.3.2-2. The site data needed to support resolution of the sealing issue are identified in Tables 8.3.3.2-3 and 8.3.3.2-4. Details of the entries are described in the discussion of the steps that follow.

There are three primary sealing components proposed for sealing the shafts and ramps: the anchor-to-bedrock plug/seal, the general fill, and the station plug. A fourth sealing component, the Topopah Spring Member, although a physical feature of the site, is included here because water drainage through this sealing component at the base of the shafts and ramps is part of the sealing strategy. Although not specifically indicated on Figure 8.3.3.2-2, the alternative of providing additional plugs/seals at various locations within the shaft exists. Similarly, if anomalous conditions occur (such as localized flow that may be significant for the underground facility), alternative components specific to the situation will be considered. In the ramps, numerous dams could be placed along the length of the ramp to periodically interrupt flow along the floor of the ramp. Alternatively, a single repository station seal placed at the end of the ramp could possibly accomplish the same function as these numerous dams and will be considered as appropriate.

Several sealing design options are proposed for sealing components within the underground facility as discussed in Fernandez et al. (1987). These options include single dams or bulkheads, double bulkheads, backfilled sumps, backfilled channels, plugs in horizontal emplacement boreholes, and drift backfill. An integral part of these sealing components is the drainage capacity of the Topopah Spring welded unit (TSw2) upgradient from the sealing component. The identification of these sealing components on Figure 8.3.3.2-3 does not suggest that all these components will be required in the underground facility. Rather, they represent options that can be emplaced in the underground facility to accommodate a broad range of water inflows, if necessary.

Exploratory boreholes drilled from the surface provide potential pathways for radionuclide migration from the repository. As a minimum, all such boreholes will be sealed or plugged according to applicable regulations. A decision on the degree of sealing required for each borehole will be made.

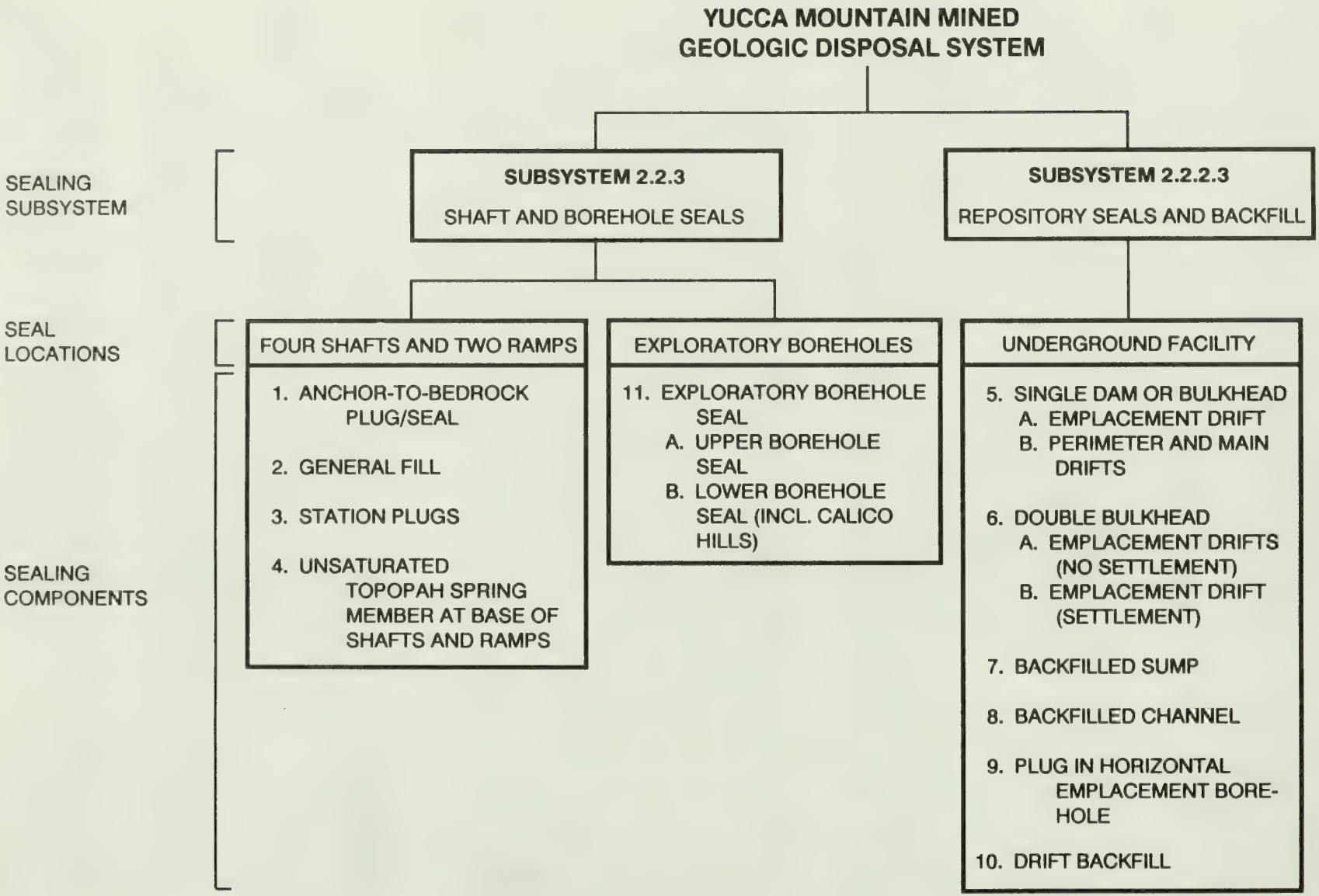


Figure 8.3.3.2-2. Sealing subsystem, seal locations, and seal components. (Identifying numbers of sealing components correspond to those used in Table 8.3.3.2-1.)

Table 8.3.3.2-1. Sealing components and associated functions, processes, material properties, performance measures, and goals (page 1 of 4)

Step A	Step B		Step C		Step D		
Sealing component	Function	Process	Material properties	Performance measure		Tentative design goal[a]	Needed confidence
SHAFT AND RAMP SEALING COMPONENTS							
1. Anchor-to-bedrock plug/seal	Reduce amount of water that could potentially reach the waste disposal rooms	Water entering the upper portion of the shaft or ramp	Permeability	Quantity of water	1A.	Limit surface waters entering shaft to 1,700 m^3/yr from 0 to 500 yr and 23,000 m^3/yr at the end of the sealing period	High
	Reduce the potential for human intrusion into the repository	Penetrability through sealing components	To be determined through design tradeoff studies	Physical presence	1B.	Deter human entry	Medium
2. General fill	Reduce the amount of water that could potentially reach the waste disposal rooms	Infiltration of surface and subsurface waters reaching the base of the shafts	Permeability of fill	Quantity of water	2A.	Restrict flow	Low
	Reduce the air flow up through shafts	Air flow up through the shaft due to convective air movement	Air permeability of fill	Percentage of gaseous radionuclides preferentially exiting shafts	2B.	Restrict gaseous releases through shaft to 1% of Environmental Protection Agency allowable release limits to accessible environment	Low
	Reduce the potential for human intrusion into the repository	Penetrability through sealing components	To be determined through design trade-off studies	Physical presence	2C.	Deter human entry	Medium
3. Station plugs	Reduce the amount of water that could potentially reach the waste disposal rooms	Water passage from the base of shaft to the waste emplacement drifts	Permeability	Quantity of water	3A.	Limit surface and subsurface waters entering the underground facility to 1,000 m^3 per yr from 0 to 500 yr and 14,000 m^3 per yr at end of the sealing period	High
4. Unsaturated Topopah Spring Member (TSw2) at base of shafts	Encourage drainage from base of shafts	Flow through the bulk rock, at base of shaft, both lined and unlined cases	Bulk rock hydraulic conductivity	Drainage capacity	4A.	Ensure uninhibited flow from the base of exploratory shaft 1 (ES-1) and the men and material (MM) shaft	High

Table 8.3.3.2-1. Sealing components and associated functions, processes, material properties, performance measures, and goals (page 2 of 4)

Step A	Step B		Step C		Step D	
Sealing component	Function	Process	Material properties	Performance measure	Tentative design goal[a]	Needed confidence
UNDERGROUND FACILITY SEALING COMPONENTS						
5. Single dam or bulkhead[b] in emplacement drifts	Retain and drain water entering emplacement drifts where water entry occurs	Lateral migration of water in drifts	Permeability	Quantity of water	5A. Retain a portion of the ground-water inflow near source by providing adequate storage volume and drainage capacity and limit flow through dam to 47 m^3/yr from 0 to 300 yr and 220 m^3/yr to the end of the sealing period (500 yr)	Medium
Single dam or bulkhead in perimeter and main drifts	Retain and drain water entering nonemplacement drifts	Lateral migration of water in drifts	Permeability	Quantity of water	5B. Promote drainage through drift floor upgradient from dam by limiting leakage through the dam or bulkhead to 10% of the drainage capacity of the drift floor upgradient from the dam, i.e., <200 m^3/yr	High
6. Double bulkheads[b] in emplacement drifts (no settlement)	Retain and drain water entering emplacement drifts where water entry occurs	Lateral migration of water in drifts	Permeability	Quantity of water	6A. Retain inflow between two bulkheads by providing adequate storage volume and drainage capacity and limit flow through bulkhead to 24 m^3/yr per bulkhead from 0 to 300 yr and 110 m^3/yr per bulkhead at the end of the sealing period (500 yr)	Low
UNDERGROUND FACILITY SEALING COMPONENTS						
Double bulkheads[b] in emplacement drifts (settlement)	Retain and drain water entering emplacement drifts where water entry occurs	Lateral migration of water in drifts	Permeability	Quantity of water	6B. Retain a portion of the inflow near source by providing adequate capacity and limit flow through bulkhead to 24 m^3/yr per bulkhead from 0 to 300 yr and 110 m^3/yr per bulkhead at the end of the sealing period (500 yr)	Low

Table 8.3.3.2-1. Sealing components and associated functions, processes, material properties, performance measures, and goals (page 3 of 4)

Step A	Step B		Step C		Step D		
Sealing component	Function	Process	Material properties	Performance measure		Tentative design goal[a]	Needed confidence
UNDERGROUND FACILITY SEALING COMPONENTS (continued)							
7. Backfilled sump[b]	Retain and drain water entering drifts	Drainage through bulk rock in floor of drift	Bulk permeability of rock at floor of drift	Quantity of water	7A.	Retain ground-water inflow near source by providing ≥ 5 m^3 temporary storage capacity ≥ 100 m^3/yr	Low
8. Backfilled channel[b]	Divert water away from waste emplacement areas	Drainage through channel fill	Permeability of channel fill	Quantity of water	8A.	Channel ground water away from waste packages at rates sufficient to handle inflow	Low
9. Plug in horizontal emplacement boreholes[c]	Reduce the amount of water entering horizontal emplacement boreholes	Infiltration through fault system	Permeability	Quantity of water	9A.	Limit flow past plug to 12 m^3/yr from 0 to 300 yr and 56 m^3/yr to the end of sealing period	Low
10. Drift backfill	Reduce the potential for subsidence	Failure of rock mass above drifts		Amount of fill	10A.	Backfill to within 0.5 m of roof	Low
	Reduce the potential of human intrusion into the repository	Penetrability through sealing components	To be determined through design tradeoff studies	Physical presence	10B.	Deter human entry	Low
EXPLORATORY BOREHOLE SEALING COMPONENTS							
11. Exploratory borehole seal							
11A. Upper borehole seal	Reduce the amount of water that could potentially reach the waste disposal rooms	Infiltration of surface and subsurface waters reaching the repository horizon	Permeability of fill	Quantity of water	11A.	Restrict flow	Low
	Reduce the air flow up through borehole	Air flow up through the boreholes due to convective air movement	Air permeability of fill	Percentage of gaseous radionuclides preferentially exiting boreholes	11B.	Restrict gaseous releases through shaft to 1% of Environmental Protection Agency allowable release limits to accessible environment	Low

Table 8.3.3.2-1. Sealing components and associated functions, processes, material properties, performance measures, and goals (page 4 of 4)

Step A	Step B		Step C		Step D	
Sealing component	Function	Process	Material properties	Performance measure	Tentative design goal[a]	Needed confidence
EXPLORATORY BOREHOLE SEALING COMPONENTS (continued)						
11B. Lower borehole seal (including Calico Hills)[d]	Reduce the potential for water transported radionuclides to be preferentially transported through boreholes	Preferential groundwater flow through the repository, Calico Hills unit and the saturated zone	Equivalent hydraulic conductivity of the borehole system	Percentage of flow	11C. Control the potential for vertical flow through boreholes to 1% or less of the potential for vertical flow through the entire rock mass	Low

[a]As used here a design goal applies to a specific sealing component and a performance goal applies to sealing subsystems such as the underground facility subsystem. Tentative performance goals for the sealing subsystems are given in Table 8.3.3.2-5.
[b]Specific sealing components will be selected as part of the design process.
[c]Probably will not be used because it is most likely that no waste would be emplaced in boreholes with water inflow.
[d]Borehole system includes the borehole seals, the interface zone, and the modified permeability zone surrounding the borehole sealing. Boreholes are categorized for sealing purposes in Table 8.3.3.2-1a.

Table 8.3.3.2-1a. Exploratory borehole categories for sealing[a,b,c]

Category A						
Within repository limits	Distance from edge of repository					Category B
	1 km	2 km	3 km	4 km	5 km	
USW H-5	UE-25a#4	UE-25WT#4	UE-25WT#5	UE-25WT#14	UE-25WT#15	USW H-3
USW G-4	UE-25a#5	USW WT-1	UE-25c#1		UE-25WT#13	USW G-3
UE-25a#6[d]	UE-25a#7		UE-25p#1			USW UZ-1
USW H-4	UE-25b#1					USW G-1
USW WT-2	UE-25a#1					USW H-1

[a]Category A boreholes represent potential pathways to the accessible environment. Category B boreholes are not believed to be potential pathways to the accessible environment but because of their proximity to the repository boundary are currently planned to be sealed.
[b]Shallow boreholes that do not require sealing for repository purposes will be backfilled or sealed as required by other regulations.
[c]The zone of influence, and hence those additional holes that may need to be sealed, will be further analyzed based on data gathered during site characterization.
[d]This borehole does not penetrate the repository horizon.

Table 8.3.3.2-2. General design constraints passed to Issue 1.11, configuration of underground facilities (postclosure), for major repository features from sealing program (page 1 of 3)

Step A	Step B		Step C	Step D	
Major repository feature	Function	Process	Performance measure	Tentative design goal	Needed confidence
12. Shafts and ramps	Provide entry into repository	Water flow in shafts and ramps	Location of surface entry	12A. Place portals of shaft and ramps outside of flood-prone areas	High
		Water flow in shafts and ramps	Number of entry points into the repository	12B. Restrict the number of shafts and ramps	High
13. Shafts	Provide entry into repository	Retain capability for permanent seal installation	Ease of liner removal	13A. Ensure shaft liner can be removed, especially at the base of the shaft	High
		Limit potential for preferential pathway	Depth of shaft	13B. No shafts should penetrate into the Calico Hills unit. Penetration by exploratory shaft 1 (ES-1) is being evaluated	High
		Encourage shaft inflow drainage at base of shaft	Water storage capacity at base of shaft	13C. 150 m^3 (backfilled assuming porosity of 0.3)	High
		Limit potential for preferential pathway	Effective thickness of the zeolitic portion of the Calico Hills unit between the lowest portion of the exploratory shaft facility (ESF) and the ground-water table	13D. The thickness between the bottom of ES-1 or any ESF drifting and the ground-water table should be greater than the minimun thickness of the Calico Hills unit above the water table anywhere within the repository boundary	High

Table 8.3.3.2-2. General design constraints passed to Issue 1.11, configuration of underground facilities (postclosure), for major repository features from sealing program (page 2 of 3)

Step A	Step B		Step C	Step D	
Major repository feature	Function	Process	Performance measure	Tentative design goal	Needed confidence
14. Underground drifting	Provide access to waste disposal areas	Potential water flow in underground facility	Drift grade	14A. Establish drainage pattern from emplacement drifts to non-emplacement drifts	High
			Drift grade in vicinity of ES-1, ES-2, and men and material (MM) shafts	14B. Establish drift grade so that the drifts associated with the ESF, the waste emplacement support shops, and the development support shops drain toward the ES-1 or MM shafts	High
			Drift grade	14C. Establish grades access and emplacement drifts so that no drainage occurs into ES-1 and MM shaft	High
			Water storage capacity in low point of repository	14D. Provide 10,000 m^3 of water storage capability before any water enters the waste emplacement drifts (assume drifts are backfilled with backfill having porosity of 0.3)	High

Table 8.3.3.2-2. General design constraints passed to Issue 1.11, configuration of underground facilities (postclosure), for major repository features from sealing program (page 3 of 3)

Step A	Step B		Step C	Step D	
Major repository feature	Function	Process	Performance measure	Tentative design goal	Needed confidence
14. Underground drifting (continued)			Ease of restoring drift floors to enhance drainage	14E. Ensure the compacted tuff on drift floors in selected areas can be removed and the floor reconditioned to enhance drainage	High
15. Underground facility	Prevent complication of seals installation	Standoff from exploratory boreholes	Ease in sealing exploratory boreholes within the repository boundary	15A. Drifting should be at least 15 m from exploratory boreholes	High
16. Shafts and underground facility	Prevent complication of seal evaluation and emplacement	Limit chemical alteration in seal environment	Ease of emplacing a grout curtain in selected locations where seals are currently proposed	16A. No grouting should take place at these locations during the construction period	High
		Limit blast-induced permeability changes	Ease of restoring the modified permeability zone in selected locations where drift seals are proposed	16B. Reduce the potential for fracturing rock in selected seal locations by exercising as much control as possible and practical, while excavating the shaft, ramps or drifts in these locations	High

[a]As used here, a design goal applies to a specific sealing component and a performance goal applies to sealing subsystems such as the shafts and ramps subsystem and the underground facility subsystem. Tentative performance goals for the sealing subsystem are given in Table 8.3.3.2-5.

Table 8.3.3.2-3. Hydrologic-related site parameters needed to support resolution of Issue 1.12 (seal characteristics) (page 1 of 3)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A, 2A, 3A, 11A, 11B	Saturated hydraulic conductivity of alluvium	Within 75 m of shaft and borehole locations	1×10^{-5} to 1×10^{2} cm/s	Medium	Low	1×10^{-2} to 1×10^{-3} cm/s	8.3.1.2.2
1A, 2A, 3A, 11A, 11B	Saturated bulk rock hydraulic conductivity of Tiva Canyon Member		1×10^{-5} to 1×10^{-2} cm/s	Medium	Low	1.2×10^{-3} cm/s	8.3.1.2.2
1A, 2A, 3A, 11A	Morphology of bedrock surface	In order of priority: downgradient and about 160 m from shaft and borehole locations	Determine contours to within ±3 m	Medium	Low	Contours accurate to 3 m	8.3.1.14.2
1A, 2A, 3A, 11A, 11B	Thickness of alluvium	Within 75 m of shaft and borehole locations	Determine thickness to within ±10%	Medium	Low	0 to 10 m	8.3.1.14.2
1A, 2A, 3A, 11A	Quantity of water due to surface flooding events 100- and 500-yr flood & probable maximum flood including area of inundation and debris load of flows	Determine parameter at shaft, ramp and borehole locations	Inundation maps with elevation of inundated area to within ±2 m	Medium	Low	(see Figure 6-8)	8.3.1.16.1
			Estimates of debris quantity and category	Low	Low	Not available	8.3.1.16.1
			Determine topography of drainage area using 2 m contours	Medium	Medium	Contours to 2 m	8.3.1.14.1

Table 8.3.3.2-3. Hydrologic-related site parameters needed to support resolution of Issue 1.12 (seal characteristics) (page 2 of 3)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A, 2A, 3A, 11A	Continuous saturation profile of alluvium to bedrock-alluvium interface	At shaft and borehole locations	±10% of natural saturation every meter	Medium	Low	To be determined	8.3.1.2.2 8.3.1.14.2
1A, 2A, 3A, 11A	Gradation of alluvium	At shaft locations predominantly within 15 m from shaft and borehole locations	Determination through standard sieving analyses	Not applicable	Low	Soils classified as GP to GM as per ASTM D-2487-83[c]	8.3.1.2.2 8.3.1.14.2
1A, 2A, 3A	Extent and hydraulic conductivity of the modified permeability zone (MPZ)	MPZ in TCw and TSw2	Less than or equal to 60 times the undisturbed, rock mass hydraulic conductivity (saturated), averaged over one radius from the wall of the shaft	Medium	Low	1 to 20 times undisturbed, rock mass hydraulic conductivity	8.3.1.2.2
1A, 2A, 3A, 11A, 11B	Unsaturated hydraulic, matrix properties	TSw2, especially in vicinity of shafts	1×10^{-8} to 1×10^{-15} m/s	Medium	Low	1×10^{-8} to 1×10^{-15} m/s	8.3.1.2.2
5A, 5B, 6A, 6B, 7A, 8A	Drainage capacity	TSw2 at selected drift floor locations at repository horizon	Saturated, bulk rock hydraulic conductivity $K_{SAT}d > 1 \times 10^{-5}$ cm/s	High	Low	1.2×10^{-3} cm/s	8.3.1.2.2

Table 8.3.3.2-3. Hydrologic-related site parameters needed to support resolution of Issue 1.12 (seal characteristics) (page 3 of 3)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
4A	Drainage capacity	TSw2 at base of shafts	Saturated, bulk rock hydraulic conductivity $K_{SAT} > 1 \times 10^{-5}$ cm/s	High	Low	1.2×10^{-3} cm/s	8.3.1.2.2
4A, 11C	Saturated, bulk rock hydraulic conductivity	CHn1 at base of ES-1 and in boreholes	Saturated, bulk rock hydraulic conductivity $K_{SAT} > 1 \times 10^{-5}$ cm/s	Low	Low	2.4×10^{-4} cm/s	8.3.1.2.2
4A	Magnitude of water entering shafts	At ES-1, ES-2, MM and EE shafts	<150 m^3/yr per shaft considering anticipated processes	Low	Low	0-100 m^3/yr	8.3.1.2.2
1A, 2A, 3A	Erosion potential	At ES-1, ES-2, MM and EE shafts	<1 m per 1,000 yr preferential erosion at shaft entry points	Low	Low	<40 cm per 1,000 yr preferential erosion at shaft entry points	8.3.1.16.1 8.3.1.6.2 8.3.1.6.1

[a]Design goals identified here are from Table 8.3.3.2-1.

[b]Thermal/mechanical units used in the modifier column are as follows: TSw2 = Topopah Spring, welded (repository horizon); TCw = Tiva Canyon, welded; CHn1 = Calico Hills, nonwelded. Other abbreviations are as follows: ES-1 and -2 = exploratory shafts 1 and 2; MM = man and material shaft, EE = emplacement area exhaust shaft.

[c]GP = poorly graded gravel; GM = silty gravel.

[d]K_{SAT} = saturated hydraulic conductivity.

Table 8.3.3.2-4. Miscellaneous information needed to support resolution of Issue 1.12 (page 1 of 4)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A, 2A, 3A, 10A, 11A	Compressive strength of rock mass	TCw at shaft and ramp locations	No more restrictive than for Issue 1.11	Medium	Low	See Table 6-12	8.3.1.4.2 8.3.1.15.2
		TSw2	No more restrictive than for Issue 1.11	Medium	Low	See Table 6-12	8.3.1.4.2
		CHn1	No more restrictive than for Issue 1.11	Medium	Low	See Table 6-12	8.3.1.15.2
1A, 2A, 3A, 10A, 11A	In situ stresses	In TCw, TSw2, and CHn1	Vertical stress accurate to ±1 MPa	Low	Low	4 to 10 MPa vertical	8.3.1.15.2
			Horizontal stress accurate to ±2 MPa			Horizontal to vertical ratio 0.3 to 1.0	8.3.1.15.2
1A, 2A, 3A, 5A, 5B, 6A, 6B, 7A, 11A	Seismic response spectra	At shaft and ramp location (surface and repository horizon) At selected location in underground facility In Calico Hills unit for boreholes within boundary of the underground facility	To be determined through design studies	High	Low	Acceleration <0.65g	8.3.1.8.2

Table 8.3.3.2-4. Miscellaneous information needed to support resolution of Issue 1.12 (page 2 of 4)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A	Meteorological environment (continued)						
	Temperature variations at ground surface	At ground surface At shaft and ramp entry points	To be determined by laboratory testing and activities	To be determined by laboratory and design activities	Low	-14 to 114°F	8.3.1.12.1
	pH of rainfall	At shaft and ramp location	>4.5	Medium	Low	pH >6	8.3.1.12.1
1A	Chemistry of alluvium	At end upgradient from shaft location					
	Dissolved sulphates SO^{2-}	At end upgradient from shaft location	<0.10% soluble SO^{2-} in soils or surface water <150 ppm dissolved SO^{2-}	Low	Low	<15 mg/L (see Table 3-3)	8.3.1.14
	pH of alluvium	At end upgradient from shaft location	>4.5	Medium	Low	>7 (see Table 3-3)	8.3.1.14
1A, 3A, 5A, 5B, 6A, 6B, 7A, 11	Geochemistry	TCw, TSw2, CHn1v, CHn1z	No more restrictive than for Issue 1.1	Medium	Low	See Section 4.1.1	8.3.1.3.2

Table 8.3.3.2-4. Miscellaneous information needed to support resolution of Issue 1.12 (page 3 of 4)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A, 3A, 5A, 5B, 6A, 6B, 7A, 10A, 11A	Maximum temperature at seal locations	Upper portion of shaft	<90°C	High	Low	<90°C	8.3.2.2.6
		At repository horizon around shaft	To be determined through design tradeoff studies	TBD[c]	TBD	<115°C	8.3.2.2.6
		At selected drift locations in repository horizon	To be determined through design tradeoff studies	TBD	Low	<150°C	8.3.2.2.6
		Calico Hills unit in boreholes below the repository	<90°C	High	Low	<90°C	8.3.2.2.6
3A, 5A, 5B, 6A, 6B, 7A, 9A, 11A	Thermal expansion, heat capacity, and thermal conductivity of seal emplacement environment	TSw2 CHn1	To be determined through design trade-off studies	Medium	Low	See Table 6-16	8.3.1.4.2 8.3.1.14.2
2A, 2B	Shaft and ramp fill properties						
	Saturated hydraulic conductivity		1×10^{-2} cm/s	High	Low	1×10^{-2} to 1×10^{-6} cm/s	8.3.3.2.2 8.3.3.2.4
	Gradational analyses, angle of internal friction, compressibility		To be determined through design trade-off studies	High	Low	Not applicable	8.3.3.2.2 8.3.3.2.4

Table 8.3.3.2-4. Miscellaneous information needed to support resolution of Issue 1.12 (page 4 of 4)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A, 3A, 5A, 5B, 6A, 6B, 7A, 8A, 10A	Fracture characteristics	TCw	<20 fractures/m	High	Low	<20 fractures/m	8.3.1.2.2, 8.3.1.4.1, 8.3.1.15.1
		TSw2	<40 fractures/m	High	Low	<40 fractures/m	
		CHn1 at base of ES-1	<5 fractures/m	High	Low	<5 fractures/m	
		PTn	<10 fractures/m	High	Low	<10 fractures/m	
5A, 5B, 6A, 6B, 7A, 8A, 10A	Chemistry of waters (if any) in fault including sediment content		Elemental concentration similar to those contained in Table 4-6	Medium	Low	See Table 4-6	8.3.1.3.1
5A, 5B, 6A, 6B, 7A, 8	Grade of emplacement drifts and drift dimensions	In repository	1-10%	Not applicable	High	1-10%	8.3.2.5.8, 8.3.2.2.7
11A, 11B, 11C	Casing location and condition for exploratory boreholes	All boreholes in categories A & B[c]	Location of casing to ±5 m. Conditions determined by logging and drilling records	High	Medium	See Fernandez and Freshley (1984)	8.3.3.2.4
11A, 11B, 11C	Unit contacts in exploratory boreholes	All boreholes in categories A & B[c]	Contact location ±5 m	High	Low	Not applicable	8.3.3.2.4

[a]Design goals identified are from Tables 8.3.3.2-1 through 8.3.3.2-3.

[b]Thermal/mechanical units used in the modifier column are as follows: TCw = Tiva Canyon welded; TSw2 = Topopah Spring welded (repository horizon); CHnlv = Calico Hills nonwelded, vitric; CHnlz = Calico Hills nonwelded, zeolitic; PTn = Paintbrush nonwelded.

[c]TBD = to be determined.

[d]Category A boreholes represent potential pathways to the accessible environment. Category B boreholes are not potential pathways to the accessible environment but because of their proximity to the repository boundary are currently planned to be sealed. These boreholes are identified in Table 8.3.3.2-1a.

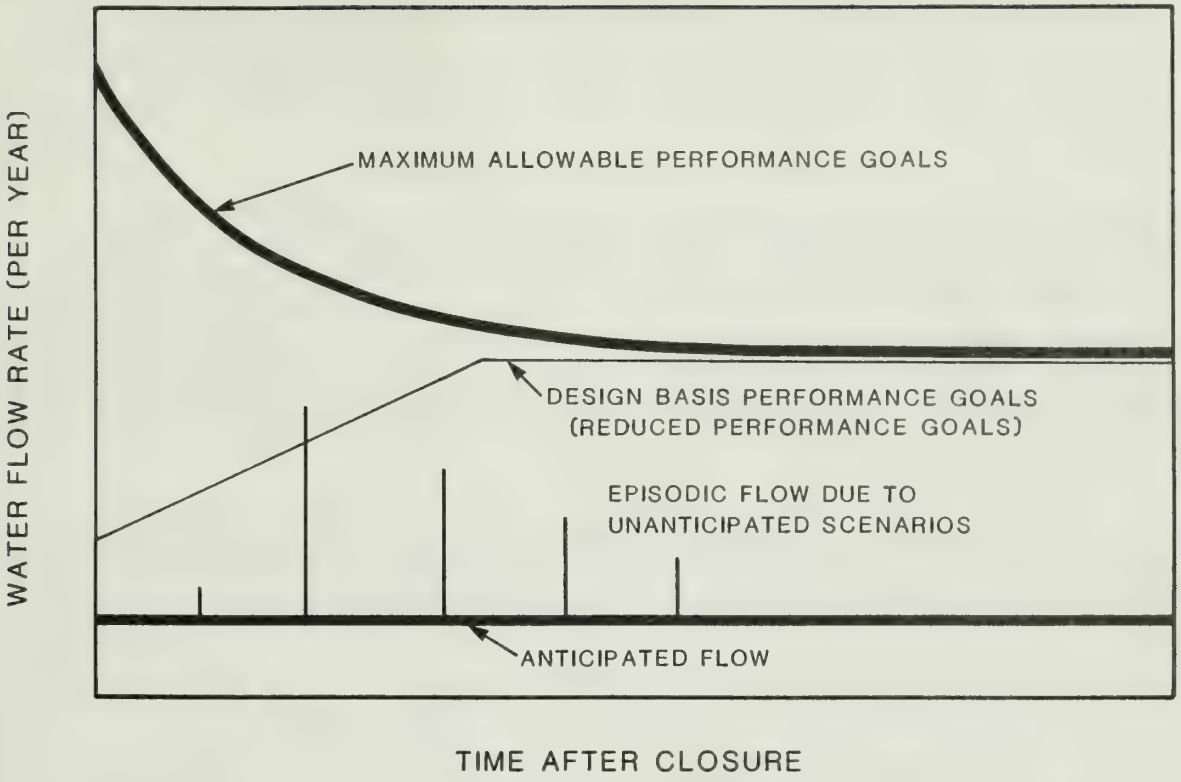


Figure 8.3.3.2-3. Schematic diagram of performance goals and relationship to anticipated and unanticipated episodic flows for sealing. (Yearly flow rate is used since the release criteria are specified on a per year basis.)

The most extensive requirements for borehole sealing are expected for those boreholes that could have some potential for waste isolation impacts. The decisions will consider factors such as distance from the repository, depth, and liquid or gaseous transport mechanisms. Preliminary evaluations of borehole sealing requirements related to water flow have been completed and are described below.

Exploratory boreholes drilled from the surface provide potential pathways for radionuclide migration from the repository to the water table. Currently, there are four existing boreholes within the proposed repository perimeter that penetrate to the water table. About 25 additional boreholes penetrate to the water table within 5 km of the repository perimeter. Among these holes, a potential pathway from the repository to the water table exists for only those holes that are downdip (generally east or northeast) from the repository, if water were to drain through the repository floor and then were to become perched at a stratigraphic contact.

Most of the existing and proposed deep boreholes penetrate through the underground facility and into the ground-water table. Shallow boreholes that penetrate into the Topopah Spring Member or overlying members are not likely candidates for borehole seals because they are not considered to represent significant liquid pathways to the accessible environment. For the purpose of identifying sealing components, boreholes that are currently planned to be sealed have been divided into categories A and B as follows.

Category A boreholes are those that represent potential pathways for water movement to the accessible environment. The further the borehole is located from the repository boundary, the lower its potential to act as a pathway to the accessible environment. Those boreholes located generally to the northeast, southeast, and east of the underground facility fall into category A.

Category B boreholes are those boreholes that are not believed to represent potential pathways for water movement to the accessible environment but, because of their proximity to the repository boundary, will probably be sealed. Those boreholes immediately to the south and north of the underground facility are included in category B. Those boreholes not included in either category are located to the west, to the far north and far south, or 5 km or more from the edge of the repository boundary. They are not included because they are neither believed to represent potential pathways to the accessible environment, nor are they close to the planned boundaries of the repository. Additional evaluations of the potential for both liquid and gaseous flow through boreholes are planned.

Step B: Define component functions and related processes

In this step of the methodology, the functions of each selected seal component are identified and the processes and mechanisms that must be considered in assessing its ability to perform its function are considered. The primary functional requirements identified for the seal program are to (1) reduce the potential for radionuclide release by controlling water and

gas flow and (2) reduce the potential for radionuclide release by discouraging human intrusions. For these general requirements, specific requirements for individual components have been developed. Some of the functions of individual components may require redefinition as more information on design and data become available, and the related design concepts are reevaluated.

Two ways that have been identified in which the shaft and ramp sealing components can reduce the radionuclide releases from the repository are to (1) reduce the amount of water that could potentially reach the waste emplacement drifts and (2) reduce the amount of airborne radionuclides that could preferentially exit from the repository. The physical processes of concern for these functions include water entry into the shafts and past sealing components and release of airborne radionuclides caused by convective air movement resulting from thermal effects in the repository.

Another functional requirement of sealing components associated with shafts and ramps is to reduce the potential for human intrusion into the repository. For this requirement, the process of concern is penetrability through the sealing component, either the anchor-to-bedrock plug/seal or the general fill.

Not all the sealing components will be relied on to achieve all the functions identified previously. For example, the anchor-to-bedrock plug/seal is not relied upon to limit gaseous releases, while the shaft fill performs this function. Conversely, more than one may be relied on to achieve the same function. For example, the anchor-to-bedrock plug/seal, the repository station seal, and shaft fill can be emplaced to reduce the amount of water entering the waste emplacement drifts. The unsaturated Topopah Spring Member (unit TSw2) at the base of the shafts could also be used to promote drainage from the base of the shafts (if any water reached the base) by allowing flow through the rock mass at the base of the shaft.

The use of multiple barriers of similar function presents the possibility of redundancy in achieving performance goals. The anchor-to-bedrock plug/seal and the shaft fill can be emplaced to reduce the potential for human intrusion. Again, emplacement of different sealing components is believed to represent a conservative approach in achieving the performance goals.

The primary function for seals located in the underground facility would be to retain and drain water entering emplacement drifts. This would be done by restricting the lateral migration of water into emplacement drifts by restricting the lateral migration of water on the drift floors. Drainage of water through floors of nonwaste emplacement areas could also add a level of redundancy to the design. Such areas could include those used for development shops, warehouse, emplacement shops, and nonemplacement drifts. Diverting waters that enter the shaft to nonwaste disposal areas would potentially reduce the amount of water entering the waste emplacement drifts.

The primary function of borehole seals is to reduce the potential for water-transported radionuclides through preferential transport in boreholes. The physical process of concern would be preferential ground-water flow through the repository, the Calico Hills unit, and into the saturated zone.

It must also be ensured that the boreholes not become preferential pathways for water flow into the repository or gaseous release out of the repository.

Processes and mechanisms influencing a component's performance will be examined as more detailed analyses are performed that characterize the response of each component. The scenario classes and processes identified for total system performance evaluations (Section 8.3.5.13) will be used as input to these analyses. Depending on the effect of the process or mechanism on the performance, the importance of the component's functions may need to be reevaluated and the design concepts modified as necessary.

Step C: Identify performance measures and goals

The purpose of this step in the methodology is to identify the performance measures that can be used to indicate the effectiveness of each sealing component in performing its intended functions.

Performance measures, as presented for this issue, are the primary qualitative measures that will be used to determine the performance of each sealing component. There are several performance measures selected within the seal program. Generally, the most important is the quantity of water passing sealing components. Others include the percentage of a certain type of flow as in the case of borehole seals and shaft seals for airborne release. Reduction of the potential for human intrusion would require the physical presence of material in the shaft. When the function is to enhance the vertical drainage of water through the Topopah Spring Member, the performance measure is drainage capacity. The preliminary list of performance measures is discussed later in this section. (Secondary properties, such as the porosity of the shaft fill, are not listed in Table 8.3.3.2-1.)

Step D: Establish performance goals

Tentative goals and required confidence in reaching each goal can be established for each measure. Analyses, using available site information and repository design information, can be used to set quantifiable values. If regulations cannot be met after a proposed design is developed, then component designs, component functions, and performance measures may have to be modified so that a revised design can be developed that will meet regulatory requirements.

As part of the preliminary performance allocation process, tentative hydrologic performance goals were established for the sealing subsystem. Details of these evaluations are documented in a report by Fernandez et al. (1987). The logic used in establishing the goals will be described in succeeding paragraphs.

In selecting performance goals for allowable water flow rates for the sealing subsystem, the results from two radionuclide release models are considered, both of which conservatively assume that all water entering the waste disposal area contacts the waste (Fernandez et al., 1987). This assumption is thought to be conservative because most water is expected to be contained within the rock matrix and, therefore, will not contact any waste packages. The differences between the two models are primarily related to differences in how the failure rate of the waste package is estimated; hence

the two models would be expected to be very similar after most of the packages are assumed to have failed. The results of both models are shown in Figure 8.3.3.2-3. The results of one model are displayed as the maximum-allowable-performance goals curve, while the more conservative model is identified as the design-basis-performance-goal curve. Hence, the approach taken in developing the preliminary performance goals for the sealing program is to use the more conservative of two models as the basis.

The first model assumes a constant rate of failure of waste packages and a release of radionuclides from areas within and outside the uranium dioxide matrix of the spent fuel. The result from this model is displayed as the maximum-allowable-performance-goals curve in Figure 8.3.3.2-3. The maximum-allowable-performance goals are based on the evaluations of the performance objectives for the engineered barrier system defined in 10 CFR 60.113. On the basis of this analysis, if the inflow to the waste packages was less than the value specified by the curve shown in Figure 8.3.3.2-3, the performance objective for gradual release from the engineered barrier system would be met. The constant waste package failure rate probably over estimates the actual failure rate, and this curve is believed to represent a conservative, but realistic, performance goal.

The second model assumes that all radionuclides are located in the matrix of the spent fuel and all waste packages fail 300 yr after repository closure. The results of this model are displayed as the design-basis-performance-goal curve shown in Figure 8.3.3.2-3. This curve incorporates the much more conservative assumption of total waste package failure at 300 yr after closure. The design-basis performance-goal curve was selected for use in the initial identification of performance goals because it is the more conservative of the two models. The differences between the two curves are primarily related to the differences in how the waste package failure rate was modeled over the first 1,000 yr; therefore, both models predict very similar allowable water flow rates after the first 1,000 yr. In summary, the preliminary hydrologic performance goals for sealing, derived from these radionuclide release models, are believed to be very conservative.

Figure 8.3.3.2-3 also shows the anticipated flow and episodic inflow from unanticipated processes and events and suggests that a seals system may not be needed at the Yucca Mountain site to meet this performance objective. However, there are uncertainties in the evaluations both for the performance goals and for the estimates of anticipated and unanticipated inflows, and the site characterization program will need to address these uncertainties. Taking into account only the need to address the performance objective of 10 CFR 60.113, the lower curve in Figure 8.3.3.2-3 (i.e., the design basis performance goals curve) provides the set of performance goals for the inflow rate. Furthermore, the preliminary performance allocation developed to date will be modified in the future to directly consider the scenario classes developed in Section 8.3.5.13 (total systems performance) for both nominal and disturbed conditions.

Numerical values for the design-basis performance goals for the sealing subsystem are identified in Table 8.3.3.2-5. The goals for the total quantity of flow are then divided (allocated) between the shafts and ramps

Table 8.3.3.2-5. Design-basis performance goals for the sealing subsystem[a]

Time after closure (year)	Design basis performance goals (m^3/year) Underground facility	Shafts and ramps	Total design-basis performance[b]
0-300	1,180	0	1,180
400	2,600	0	2,600
500	5,600[c]	90	5,690
600	5,600	6,700	12.300
700	5,600	20,900	26,500
800	5,600	50,300	55,900
900	5,600	110,400	116,000
1,000	5,600	130,400[c]	136,000
1,000-10,000	5,600	130,400	136,000

[a]Source: Fernandez et al. (1987).

[b]The total design-basis performance goal is the sum of the performance allocation for the underground facility and that for shafts and ramps.

[c]Beyond this point in time the design-basis performance goal (i.e., allowable flow rate) exceeds potential flow due to anticipated and unanticipated events. No performance of the sealing components at these locations is required after this time.

and the underground facility. The subsystem goals were then further subdivided into the tentative design goals for the various sealing components; these component goals for the components are provided in Table 8.3.3.2-1.

Reevaluation of performance goals and design requirements will occur as more design information, site data, and performance evaluations are completed during ACD and LAD. These evaluations will allow better comparison between needed and expected performance of seals.

Step E: Define performance parameters

The methodology developed to resolve Issue 1.12 includes a step to identify the specific parameters required to support an evaluation of the performance goals identified for each performance measure. This step involves identifying support parameters, establishing goals for each parameter, and estimating current and eventually needed level of confidence. The parameters are used in analyses to predict the magnitude of the performance measures defining the relationships for processes and/or mechanisms.

The parameters required to address each information need in this issue are described under the appropriate information need. The hydrologic and

miscellaneous parameter needs are shown in Tables 8.3.3.2-3 and 8.3.3.2-4 and discussed in more detail in Section 8.3.3.2.1. In general, the preliminary needed confidence for most parameters is identified as either high or medium. For some parameters a low needed confidence is assigned for meeting the tentative performance goals when the parameter is not expected to be a significant variable in licensing-related analyses. This may occur as a result of (1) a related component performance having a low needed confidence or (2) the anticipation (based on engineering judgment or preliminary analysis results) that the component performance is relatively insensitive to plausible variability in the value of the parameter.

Step F: Identify information needed to resolve the issue

As indicated in Figure 8.3.3.2-1, the information needed to respond to this issue must also be identified and transmitted to Issue 1.11 so that the postclosure underground facility design can be developed. This needed information is defined in Tables 8.3.3.2-3 and 8.3.3.2-4 and is described in the parameter sections under the appropriate information need.

Step G: Design requirements and constraints

After the functional requirements and performance allocation processes have been developed, it is necessary to define the design requirements for the seal system. This step in the issue resolution methodology identifies design requirements, design constraints imposed on nonsealing system elements, sealing strategies, and seal material specifications. The purpose of this step is to provide the design requirements necessary to develop a design that will meet the design goals and hence the performance goals.

As indicated in the first part of this section, sealing design requirements and constraints will be transmitted to Issue 1.11 (Section 8.3.2.2) to develop an appropriate postclosure design. Design requirements primarily include the quantitative and qualitative requirements imposed on the seal components to achieve a desired performance. The technical basis for the design requirements is presented in Fernandez et al. (1987).

Some general constraints placed on major repository elements by the seal program are given in Table 8.3.3.2-2. The majority of the performance measures relate to grading drifts within the underground facility to achieve the specified performance goals and to restoring the drift floors to encourage vertical drainage of water through drift floors. Other constraints include no grouting within rock in selected locations where components are proposed and ensuring that penetration into the Calico Hills unit is controlled. Finally, because drifting across exploratory boreholes could compromise the sealing efforts for these boreholes, a constraint is imposed on drifting. This constraint is not to intersect the boreholes and also to maintain a minimum distance from the boreholes. Directional logs for boreholes within the repository boundaries will be needed to aid in ensuring that this constraint can be met.

Relative to the exploratory shafts planned for Yucca Mountain, the ESF excavation techniques and shaft design conservatively attempts to limit uncertainties in the sealing program in the following principal ways:

1. Shafts are located to limit potential water inflow and thereby reduce uncertainty in seal performance.

2. Controlled blasting is used throughout shaft construction, thereby allowing installation of seals in multiple and optimal locations at closure when maximum information is known about the site behavior, sealing materials, sealing designs, and performance requirements. This reduces uncertainty in the ability to emplace the seals and to predict their performance.

3. Concrete shaft liner and temporary ground support are installed to limit rock movement and thereby reduce uncertainty in both the ability to emplace seal components and the extent of the zone of modified permeability near the shaft.

Design requirements and seal material specifications developed to date in the conceptual design process are guidelines for design analyses and future materials testing, and the requirements are very preliminary. Current design requirements are presented by Fernandez et al. (1987). Revisions and additional design requirements are expected to emerge from the advanced conceptual design and during the license application design.

Seal system performance and seal component designs are addressed directly by this issue (seal characteristics) as presented in the preceding discussion.

The planned investigations that will be used to assess the performance of proposed sealing designs and to develop design information necessary for the license application design are defined as follows:

Information need	Description
1.12.1	Site, waste package, and underground facility information needed for design of seals and their placement methods (Section 8.3.3.2.1).
1.12.2	Materials and characteristics of seals for shafts, drifts, and boreholes (Section 8.3.3.2.2).
1.12.3	Placement methods for seals for shafts, drifts, and boreholes (Section 8.3.3.2.3).
1.12.4	Reference design of seals for shafts, drifts, and boreholes (Section 8.3.3.2.4).

Information Need 1.12.1 identifies information that will be obtained from sources outside the Yucca Mountain Project repository seal program and that will influence the design and performance of the repository seals.

Information Need 1.12.2 identifies activities, primarily related to laboratory testing, needed to determine the properties of seal materials that may be used in an unsaturated tuff environment.

The placement methods of sealing components (Information Need 1.12.3) depend on the need for sealing components as determined by the appropriate activities defined by Information Need 1.12.4 and the selection of sealing materials as determined through the laboratory testing defined by Information Need 1.12.2. The bulk of the design work, including design selection, trade-off analyses, development of design requirements and design descriptions, and modeling associated with the performance of sealing components, is incorporated into the activities defined as part of Information Need 1.12.4. No computer code development is currently anticipated as part of the Yucca Mountain Project seal program. Existing computer codes developed in support of other performance analyses will be used in seal design analyses. Computer codes that have been or may be used in the seal program are named in Section 6.1.3.2.3. Depending on the verification requirements, some efforts may be required to verify results using the identified codes.

Interrelationships of information needs

The question raised by this issue is aimed at determining if the emplacement of shaft and borehole seals and seals for backfill in the underground facility shows compliance with the postclosure performance objectives.

The available site and underground facility data from Information Need 1.12.1 (Section 8.3.3.2.1) can be used to develop seal performance goals and design requirements for specific sealing components. The development of these design requirements can then be used to select designs of seals for shafts, ramps, drifts, and boreholes (Information Need 1.12.4, Section 8.3.3.2.4). Evaluation of the performance of sealing components is an integral part in the selection of the appropriate designs and, therefore, is part of Information Need 1.12.4 (Section 8.3.3.2.4). The selection of materials and characteristics for seals (Information Need 1.12.2, Section 8.3.3.2.2) and their emplacement methods (Information Need 1.12.3, Section 8.3.3.2.3) can then be made to achieve the performance established for the sealing components. Further, because the underground facility must contribute to repository performance, its design could reduce the reliance placed on drift seals. (Drift seals are part of the underground facility, but shaft and borehole seals are not.) The characteristics and configuration of the underground facility as they relate to the postclosure design criteria of 10 CFR 60.133 are discussed in Section 8.3.2.2 (configuration of underground facilities). The general criteria for the underground facility state that "the underground facility...shall contribute to the containment and isolation of radionuclides."

The schedule information for this issue is given in Section 8.3.3.2.5.

8.3.3.2.1 Information Need 1.12.1: Site, waste package, and underground facility information needed for design of seals and their placement methods

Technical basis for addressing the information need

The technical basis for addressing the information need is discussed in the following paragraphs by first identifying the contents of related sections of the SCP and other documents. Needed parameters are then described. The logic for the technical activities is described and planned design activities are identified.

Link to the technical data chapters and applicable support documents

As mentioned in the discussion under Step E, the information identified in this information need will be obtained outside the Yucca Mountain Project seal program. This information falls into two categories: site and underground facility design. Under site, the primary information needed is an understanding of the water inflow into the repository and the hydrologic characteristics of selected geologic units. This type of information is discussed in Section 3.6 (regional hydrologic reconnaissance of candidate area and site). In particular, the description of the hydrologic units and hydraulic characterization of principal hydrogeologic units will be important from a sealing perspective. Information obtained in Section 3.9 (site hydrogeologic system) as well as surface flooding in Section 3.2 (floods) will also be used in resolving this issue.

The underground design is described in Section 6.2.2, which describes the overall design of the repository, and Sections 6.2.5 and 6.2.6, which describe the shaft and ramp designs and the subsurface design. Additional details of the repository design are provided in the conceptual design report developed in support of the site characterization plan (SCP-CDR) (SNL, 1987).

Parameters

A variety of site and repository design parameters are required as part of this information need. Table 8.3.3.2-3 lists the hydrologic parameter needs, the ranges of parameters, and the confidence needed in meeting the performance goals. Table 8.3.3.2-4 presents the same information for miscellaneous (site or design) parameters. Additionally, these tables indicate what SCP sections describe the information needs that will provide values for the parameters. In all instances, a correlation is made between the design goal and the required parameter.

The majority of the parameters and parameter ranges for shaft and ramp sealing components deal with defining the potential for surface water infiltration to enter shafts. Realistic estimates can be obtained by characterizing near-surface geologic units such as alluvium and the Tiva Canyon Member. For alluvium, required parameters include saturated hydraulic conductivity, gradation, sieve analysis, saturation profiles, unsaturated properties, and thickness. The saturated hydraulic conductivity of the Tiva Canyon is also identified as a parameter need. In addition to these near-surface site parameters, the quantity of water due to surface flooding events is also identified as a parameter need. The modified permeability

zone (MPZ) is the zone immediately surrounding an underground excavation in which the permeability of the rock mass has been altered due to stress redistribution and blast damage effects. Because water flow down the shaft (under saturated conditions) can be controlled by the MPZ, knowledge of the MPZ characteristics is needed. The parameter goal range is taken from a report that developed a model for the zone surrounding a vertical penetration in welded tuff (Case and Kelsall, 1987).

If water reaches the base of the shaft, it is important to know the drainage capacity of the sump locations so that the anticipated amount of water entering the shaft can be dissipated effectively. Similarly, the drainage capacity of water through drift floors is an additional parameter for consideration in the seal program. The acceptable parameter range for the saturated, rock-mass hydraulic conductivity depend on the design option proposed and the amount of water to be drained. Nevertheless, a lower limit of 1×10^{-5} cm/s is proposed based on current design efforts. Finally, erosion potential is listed as a parameter need so that excessive erosion does not occur at the shaft entry points and subsequently increase the potential for water to enter the shafts.

In Table 8.3.3.2-4 nonhydrogeologic parameters are identified. They include the following:

1. Design information such as the dimensions of all openings where seals may be emplaced. This includes dimensions for shaft, ramps, and drifts. Information on drift grades is also required to properly design dams or bulkheads in the underground facility. Variations in drift grade do occur in the current design. Such variations can influence the area of drift floor that becomes inundated and subsequently the drainage capacity of the area upgradient from the dam or bulkhead.

2. Borehole construction and geologic logs are routinely obtained as part of the site investigation work within the Project and are necessary to establish a strategy in effectively sealing boreholes.

3. The thermal and mechanical properties (strength, modulus, conductivity, etc.) of the rock mass for selected geologic units and in situ stresses at potential seal locations are required to assess the structural response of these seals. Because structure failure could incur a decrease in hydrologic performance, it is possible that some sealing elements may not achieve their design goals. Therefore, tradeoff studies would be required to evaluate the impact of structural deformations of the rock mass (if any) on the performance of specific sealing elements. Seismic forces could also modify the properties of the sealing elements. Therefore, the seismic response spectra would be required at seal locations to evaluate the potential for modifying the properties of sealing elements.

4. Performance of near-surface sealing elements can be affected by meteorological and chemical conditions that exist at the surface.

For this reason, temperature variations at the ground surface together with two chemical parameters, pH and soluble sulphate, are identified.

5. These chemical parameters and parameter ranges are based on the current concept that the sealing material at the surface is concrete. The parameter ranges, therefore, are specifically associated with a concrete located at the surface. If it is determined through design studies, as part of the advanced conceptual design phase, that concrete is not needed and another material may be better suited, then this parameter need will be dropped.

6. Chemistry of the seal environment is included so that durability of the seal material can be assessed. The chemistry of alluvium; Tiva Canyon, welded (TCw); Topopah Spring, welded (TSw2); Calico Hills, vitric (CHv); and Calico Hills, zeolitic (CHz) are identified as being required to assess geochemical durability of the sealing element.

7. A limit on the temperatures at two potential seal locations (i.e., at the upper portion of shaft and ramps and at the Calico Hills borehole seal locations) is given in Table 8.3.3.2-4. Such limits will reduce the potential for alteration of the seal materials.

8. Calculations presented elsewhere (Fernandez et al., 1987; Fernandez et al., 1988) have shown that infiltration of surface waters into a shaft fill can be acceptably reduced and retarded if the saturated hydraulic conductivity of the shaft fill is less than 1×10^{-2} cm/s. Air flow through shaft fill can also be acceptably reduced assuming the same saturated, hydraulic conductivity. These sensitivity analyses evaluated possible ranges in air and water flow through the shaft and surrounding rock. Values for hydraulic or air conductivities were varied for the rock mass, the shaft fill, the modified permeability zone near the shaft, and, in some cases, the overlying alluvium. For example, the rock mass hydraulic conductivity for one analysis (Fernandez et al., 1987) was varied from 10^{-2} to 10^{-5} cm/s. Gradational analyses, angle of internal friction, and compressibility of the shaft fill will also be necessary to determine if excessive settlement of the shaft fill could occur. Excessive settlement, if taken to the surface (assuming the emplacement of no anchor-to-bedrock seal), could increase the potential for more surface waters to enter the shaft.

9. Sealing fractures around selected sealing elements may be required to achieve a desired level of performance. Therefore, the thermal/mechanical units that may require some fracture characterization would be Tiva Canyon, welded (TCw); Topopah Spring, welded (TSw2); Calico Hills, nonwelded (CHn1); and the Paintbrush Tuff, nonwelded (PTn). Using this data, effective plans to seal these fracture zones could be developed.

10. The remainder of the required parameters may not be available at the time that testing is completed in the exploratory shaft facility. Specifically, if water-producing zones are encountered it would be

appropriate to characterize the chemistry of the fault zone waters including the sediment content, if any. This data could then be used to evaluate the potential for reducing the drainage capacity of the drift floor or perhaps reducing the effectiveness of the seal component that it contacts. The measurement of the volume of waters draining into drifts could also suggest the amount that could enter horizontal emplacement holes.

Logic

The geomorphology, meteorology, and surface hydrology of the shaft and ramp locations, the risks of flash flooding, the configurations of the shafts and ramps, and the geotechnical properties of the near-surface alluvium and bedrock are required for the design of the shaft sealing components. The properties and depth of the alluvium must also be known to predict the potential for ground-water inflow to the shafts through the alluvium.

Information about the hydrologic properties of the stratigraphic units penetrated by the shafts is needed to determine the potential for ground-water inflow into the shafts and the underground facility. Initially, the inflow will be predicted based on data obtained from boreholes, available analytical solutions, and the hydrologic properties of the stratigraphic units at Yucca Mountain. Later, an indication of the potential inflow will be determined from direct observation of water inflow during and after construction of the exploratory shafts and the underground test facility. The stratigraphy and the configuration of the shaft, including the shaft station, will be used to determine suitable locations for shaft seals should they be necessary. For example, seals may be necessary below certain stratigraphic contacts at which ground-water perching could occur. The drainage capacity of the base of the shaft will be assessed to determine whether ground-water inflow would drain from the sump rather than flow into the repository.

The waste emplacement mode (i.e., vertical or horizontal) selected for the repository may influence the types of seals that are selected. For example, if the horizontal mode is selected, ground-water inflows to drifts may have no impact on the waste. The location of the repository including the ramps with respect to faults may influence the occurrence of ground-water inflow from discrete fault zones. The amount of inflow may be influenced by the hydrologic properties (permeability and porosity) of the fault zones and by the size of the underground opening and its orientation with respect to the fault. Initially, the amount of ground-water inflow will be predicted from surface observations and borehole data. Later, the predictions will be revised according to observations of inflows and fracture characteristics in the exploratory shaft test facility. The predicted rates of inflow will then be compared against the measured drainage capacity of the drift floors. During the testing associated with the exploratory shaft facility, drainage capacity of the densely welded tuff will be determined. The bulk permeability and infiltration tests will provide data on the ability of the repository to drain waters that may enter the repository.

Construction details associated with exploratory boreholes drilled from the surface are required to select appropriate seal designs. Characteristics

of interest include location, depth, drilling history (including any lost circulation zones), and casing configuration.

Information about the physical, mechanical, chemical, and thermal properties of stratigraphic units, including those encountered in the shafts and ramps as well as in the repository, are required to ensure that seals, as designed, can withstand in situ hydraulic, structural, chemical and thermal loads. The extent and properties of the modified permeability zone around openings are needed for analysis of total ground-water flow through seal zones and, possibly, for the design of seal emplacement methods. In situ stresses, seismicity, and the temperature at possible seal locations are also required for structural and thermal analyses.

All the data required to satisfy this information need will be obtained from site characterization activities described elsewhere in the SCP. Sealing-related activities are included in the discussions in Sections 8.3.3.2.2, seal material; 8.3.3.2.3, placement methods; and 8.3.3.2.4, reference seal designs.

8.3.3.2.1.1 Application of results

The data obtained from this information need will be used to support all aspects of the seal program, including evaluating the performance of sealing elements, developing detailed designs, and planning of laboratory and field tests. The primary focus will be Information Need 1.12.4 (8.3.3.2.4). The output from Information Need 1.12.4 will then be transmitted to Information Need 1.11.7 (Section 8.3.2.2.7), reference postclosure underground facility designs.

8.3.3.2.2 Information Need 1.12.2: Materials and characteristics of seals for shafts, drifts, and boreholes

Technical basis for addressing the information need

The technical basis for addressing the information need is discussed below by first identifying the contents of related sections of the SCP and other documents. Needed parameters are then described. The logic for the technical activities is described and planned design activities are identified.

Link to the technical data chapters and applicable support documents

Two basic areas that will support the seal material development effort include geochemistry of the emplacement horizon and the in situ and anticipated alterations on the rock mass due to the existence of the repository. Information on geochemistry (Chapter 4) is included in Section 4.1, geochemistry of the host rock and surrounding units. Information on the alteration of the host rock is included in Section 4.2 (geochemical effects of waste emplacement); Chapter 2 (dealing with the geoengineering properties

of the rock mass due to excavations); and Section 7.1 (emplacement environment) of Chapter 7.

The main purpose in obtaining the geochemical information will be to confirm the geochemistry of the ground waters and rock units at the repository horizon. Additional geochemical information will be needed if seal materials are chemically different from the medium into which they are placed. Geochemical information collected will also be used to confirm the predicted effects due to the presence of the repository, specifically the temperature elevation in the emplacement medium.

Parameters

Materials and material properties of concern will be defined following the development of the design requirements. Repository seals, if needed, will be designed to limit the ground-water flow into or out of the repository and potential gaseous transport from the repository. Since the most important parameters or material characteristics are yet to be determined through the continuing design requirements effort (Information Need 1.12.4, Section 8.3.3.2.4), potentially important material properties only can be defined. These potential material properties are presented in Table 8.3.3.2-6. Material properties include those related to placement as well as performance.

Parameter ranges and confidence in parameter ranges for seal properties are not presented in Table 8.3.3.2-6. These values will be determined by the design activities described in Section 8.3.3.2.4. Selection of the parameter ranges will depend on the ability and need to achieve the performance goals discussed in Section 8.3.3.2.1 (information needed for seal design). Parameter ranges and confidence levels for pertinent site information are given in Section 8.3.3.2.1.

To accommodate the potential need for man-made materials and crushed tuff, laboratory testing is proposed. The testing scope will be modified, if necessary, as the seal design requirements are defined in more detail. Because emplacement conditions may vary within the underground facility, a broad range of environmental conditions will be considered in the laboratory testing of cementitious-based materials. The data obtained as part of the site characterization effort, that is, the geochemistry of the emplacement horizon and the repository design activities (temperature histories and mechanical properties of the repository unit), will confirm environmental conditions to be encountered. Any information on seal materials and their characteristics that is needed will be obtained as part of this information need.

Logic

Physical and mechanical properties of candidate seal materials must be known to select materials that will resist imposed structural loads. Early age properties of some materials (e.g., slump and viscosity in grouts or concretes) are required for selection of appropriate placement methods.

Hydrologic properties of candidate seal materials must be known to select suitable materials that meet design requirements for reduction of

Table 8.3.3.2-6. Potentially important material properties of concern for sealing components

Categories of properties	Specific material properties	Reason required
Initial and altered physical properties of materials	Density, porosity, compressive strength, Young's modulus, Poisson's ratio, modulus of rupture, shear strength, expansivity, bond strength, viscosity, slump (concrete, grouts), tensile strength, creep of seal material, drying shrinkage strain	Structural analysis, settlement analysis, interface stress development, selection of emplacement method
Initial and altered hydrologic properties of materials	Compressibility gradation, porosity (total and effective), saturated hydraulic conductivity, interface hydraulic conductivity	Hydrologic analysis
Initial thermal properties of materials	Thermal conductivity, specific heat, heat of hydration (concrete, grouts), thermal expansion	Thermomechanical analysis, interface stress development
Material reactivity and stability (longevity) in seal zone	Overall composition, composition and proportion of phases, particle size, solubility of phases and precipitation, phase transformations (including dehydration), microbial activity, thermodynamic properties, chemical properties of leachate	Evaluation of durability of seal materials

ground water. Additionally, hydrologic properties are also required for performance assessment of the seal system.

Thermal properties of candidate seal material must be known for analysis of the response of seals to thermal loads. The mineralogy and chemistry of candidate seal material must be known to evaluate possible adverse interactions between the materials and the host rock and ground water.

Emplacement conditions (e.g., temperature, presence of free water) and emplacement method (e.g., degree of consolidation of concretes or degree of compaction of granular materials) can influence the material properties. These conditions will be considered in the selection and design of seals.

8.3.3.2.2.1 Study 1.12.2.1: Seal material properties development

8.3.3.2.2.1.1 Activity 1.12.2.1.1: Detailed property determination of cementitious-based and earthen materials

Objectives

The objective of this activity is to initiate laboratory testing to determine material properties for sealing elements needed to resolve this issue.

Description

Before initiating laboratory testing, a detailed plan will be prepared indicating the parameters to be measured and how these parameters will be used to resolve the issue of materials longevity. Currently, it is believed that this plan will include details of laboratory testing involving potential alteration of sealing materials and response of sealing materials in restrained environments.

Because the durability of sealing materials in anticipated environments cannot be evaluated in real time, thermodynamic models, supported by laboratory experiments, will be used to understand the potential for alteration of sealing material and their properties. Input from theoretical studies (i.e., thermodynamic models such as the degradation model) will be used to define suitable materials for testing. The program will then include periodic characterization and testing to determine progressive alteration in properties after the materials are subjected to various experimental conditions (such as temperature and moisture conditions) for successively greater lengths of time. Experimental conditions will also consider the conditions of the seal environments. Other tests may determine the volume stability of the seal material within a block of tuff to determine the long-term performance of the interface. In general, material properties such as those identified in Table 8.3.3.2-6 will be determined to assess if the design goal for a sealing components can be achieved.

8.3.3.2.2.1.2 Activity 1.12.2.1.2: Hydraulic conductivity and consolidation testing of crushed tuff

Objectives

The objective of this activity is to establish the hydraulic conductivity and consolidation behavior of crushed tuff to support the development of criteria for shaft fill and drift backfill.

Description

To establish an acceptable hydraulic conductivity, gradation, and density of compacted shaft fill, laboratory studies will be required. Because mining and processing of tuff create very fine-grained material, tests will be performed on at least two gradations of welded tuff: one optimally graded to enhance drainage and reduce settlement and one that contains fine-grained particles. The source material for this laboratory analysis will be tuff extracted through the mining of the exploratory shaft. Specific tests will characterize the gradation, compaction characteristics, and the saturated hydraulic conductivity for the various samples.

8.3.3.2.2.2 Design Activity 1.12.2.2: A degradation model for cementitious materials emplaced in a tuffaceous environment

Objectives

The objective of this activity is to develop a degradation model that will provide insight into how material properties of sealing components, especially permeability and strength, could alter after being in contact with tuff.

Description

Because the phase assemblages of grout and concrete probably will not be in thermodynamic equilibrium with tuff, phase transformations may occur. The rate of alteration will be enhanced because of the elevated temperatures surrounding the waste package. Therefore, one approach in developing a degradation model is to assess the impact that alteration of the phases present can have on the material properties of concern. Testing will be required to obtain the data on phase transformations, dissolution, or precipitation in the seal-host system.

Changes in mineralogy may affect solubility of phases in the cementitious material, induce volumetric changes that could increase or decrease the permeability and strength of the grout, and change the matrix and bond strengths. Therefore, the final output from this task will be a qualitative assessment of how the structural, hydrologic, and chemical properties of cementitious-based sealing material can change in their emplacement environment.

8.3.3.2.2.3 Study 1.12.2.3: In situ testing of seal components

Objectives

The objective of this study is to initiate in situ testing to evaluate the behavior of selected sealing components under realistic in situ conditions as well as under unlikely conditions.

Description

This section presents the process to determine the need for in situ testing of sealing components. The process includes the following steps:

1. The first step is an evaluation of current information needed to resolve performance/design/emplacement issues of the seal system as identified in the SCP and the technical basis report for sealing (Fernandez et al., 1987). The needed information is categorized into three groups: (a) specific properties of the site, primarily hydrologic properties, (b) properties of seal materials and the seal environment after waste package emplacement, and (c) specific properties of sealing materials necessary to ensure adequate emplacement.

2. The second step is an evaluation of the adequacy of the data by comparing the current confidence with the needed confidence in the data and the current state of the art in emplacing sealing components to achieve specific performance goals.

3. The third step is definition, evaluation, and selection of in situ tests of seal components. This step includes an understanding of the environment anticipated for seal components obtained from the site characterization program. Evaluations of the ability to reduce uncertainties in seal performance also includes evaluating the significance of the sealing subsystem in achieving the overall performance objective of the repository performance objective. Finally, it includes a refinement of the seal design considering site properties and the role of the sealing subsystem in overall repository performance.

4. The final step is detailed definition and design of specific field test(s) to evaluate performance of seal components. This includes laboratory test results to refine the scope of the field test. It can also include the impact of performing the test at specific locations.

Currently, the first two steps of the process just defined are completed and are discussed below. Steps 3 and 4 cannot be completed until some of the information from the site characterization program is obtained.

Information needed

The first step of the process evaluates the information needed. In the following discussion, SCP activities that contribute to the resolution of Issue 1.12 (this issue) are considered since the sealing program depends on

diverse activities of the repository program to provide the information required to assess the need for sealing and to develop design requirements. The information needed falls into three categories:

1. Specific site properties (Table 8.3.3.2-7).

2. Seal material properties and altered properties of the seal emplacement environment (Table 8.3.3.2-8).

3. Seal material properties related to seal emplacement concerns (Tables 8.3.3.2-9a and -9b).

Tables 8.3.3.2-3 and 8.3.3.2-4 identify the properties needed with the appropriate modifiers, the tentative goals for the specific properties, the needed and current confidence in achieving the property values. SCP activities that will determine the value of the specific property are identified in Tables 8.3.3.2-7 and 8.3.3.2-8.

The following sections discuss the second-step evaluations: the adequacy of the existing data and state-of-the-art considerations.

Adequacy of data--site properties. The site properties identified in Table 8.3.3.2-7 will be evaluated by existing SCP studies and activities. In certain instances existing plans may not precisely designate specific locations for property or inflow determinations. However, appropriate locations are expected to be identified through future planning.

The ability to disperse water that flows to the repository via shafts and intersected fault zones is primarily a function of the infiltration rate of water into the floor of the repository in the Topopah Springs welded tuff. The infiltration test planned for the exploratory shaft (Section 8.3.1.2.2.4.2) will ascertain the infiltration rate in the Topopah Spring unit, but will provide little information regarding the spatial variability of infiltration rates at the repository horizon. Other similar tests may need to be considered for drifts that explore the repository horizon, such as the drifts planned to investigate the fault zones present within the repository limits. The results of these tests may allow correlation with observations of the macroscopic features of the rock to allow estimates of infiltration rates for other areas of the repository horizon.

An additional issue is a question of the effects of fines on the infiltration rate as a function of time. The shafts and drifts will ultimately be filled with an engineered backfill having specific hydraulic properties. Through time, it might be expected that the finer particles will migrate downwards and could potentially alter the infiltration properties at the base of the shaft or at the repository horizon where hydraulic conductivity is derived largely from fracture porosity. The extent to which fines may affect the fracture permeability can be investigated through design studies and laboratory and field testing, possibly as an addition to the existing infiltration test in the exploratory shaft.

Needed rock properties within the repository are also given in Table 8.3.3.2-7. Again, the bulk of these properties will be generated by existing planned activities with the exception of items such as seismic

Table 8.3.3.2-7. Site properties needed for Issue 1.12 (seal characteristics)

Properties	SCP sections
Saturated hydraulic conductivity of alluvium near shafts	8.3.1.2.2.1.1, 8.3.1.2.2.3.1, 8.3.1.2.2.3.2
Saturated bulk rock hydraulic conductivity of Tiva Canyon Member	8.3.1.2.2.3.2, 8.3.1.2.2.4.4
Morphology of bedrock surface near shafts	8.3.1.4.2.1
Thickness of alluvium near shafts	8.3.1.2.2.1.1, 8.3.1.4.2.1, 8.3.1.14.2.1.2, 8.3.1.14.2.1.3
Quantity of water due to surface flooding events 100 and 500 yr flood and probable maximum flood including area of inundation and debris load of flows at shaft and ramp locations	8.3.1.2.1.2, 8.3.1.2.1.2.2, 8.3.1.14.1, 8.3.1.16.1.1.1
Continuous saturation profile of alluvium to bedrock-alluvium interface at shaft locations	8.3.1.2.2.1, 8.3.1.2.3.1, 8.3.1.14.2.1.2, 8.3.1.16.1.1.1
Gradation of alluvium at shaft locations	8.3.1.2.2.1.1, 8.3.1.14.2.1.2, 8.3.1.14.2.1.3
Extent and hydraulic conductivity of the modified permeability zone (MPZ) in welded Tiva Canyon unit (TCw) and Topopah Spring welded (few lithophysae) unit (TSw2)	8.3.1.2.2.4.4
Unsaturated hydraulic, matrix properties of TSw2	8.3.1.2.2.3.1, 8.3.1.2.2.3.2
Drainage capacity of TSw2 at selected drift floor locations at repository horizon and base of shafts	8.3.1.2.2.3.1
Saturated, bulk rock hydraulic conductivity of Calico Hills nonwelded unit (CHn1) at base of exploratory shaft 1 (ES-1), if drilled into CHn1, and in boreholes	8.3.1.2.2.4.4, 8.3.1.2.2.4.6
Magnitude of water entering shafts	8.3.1.2.2, 8.3.1.16.1.1.1

Table 8.3.3.2-7. Site properties needed for Issue 1.12 (seal characteristics) (continued)

Properties	SCP sections
Erosion potential in shaft vicinity	8.3.1.6.1.1, 8.3.1.6.2.1, 8.3.1.16.1
Compressive strength of rock mass (TCn, TSw2, and CHn1) at shaft and ramp locations	8.3.1.15.1.3.1
In situ stresses in TCn, TSw2, and CHn1	8.3.1.15.2.1.1, 8.3.1.15.2.1.2
Seismic response spectra at selected areas in shafts ramps, and underground facility	8.3.1.8.2.1.5, 8.3.1.17.3.5, 8.3.1.17.3.6
Meteorological environment	
Temperature variations at ground surface at shaft and ramp entry points	8.3.1.2.1.1
pH of rainfall	8.3.1.12.1.1
Chemistry of alluvium at shaft locations	
Dissolved sulphates SO_4^{2-}	8.3.1.3.1.1
pH of alluvium	8.3.1.3.1.1
Geochemistry of TCn, TSw2, and vitric and zeolitized CHn1, (CHn1v and CHn1z)	8.3.1.3.2.1
Thermal expansion, heat capacity, and thermal conductivity of seal emplacement environment especially at TSw2 and CHn1	8.3.1.4.2.2, 8.3.1.15.1.1, 8.3.1.15.1.2, 8.3.1.15.1.3
Fracture characteristics of TCn, TSw2, CHn1 at base of ES-1, if drilled into CHn1 and Paintbrush nonwelded unit (PTn)	8.3.1.4.2.2
Chemistry of waters (if any) in fault including sediment content	8.3.1.3.1.1
Moisture flux beneath the repository horizon	8.3.1.2.2.1.2, 8.3.1.2.2.4.1

Table 8.3.3.2-7. Site properties needed for Issue 1.12 (seal characteristics) (continued)

Properties	SCP sections
Infiltration rate for unanticipated conditions	8.3.1.2.1.1, 8.3.1.2.2.1
Future climatic conditions	8.3.1.5.1.1, 8.3.1.5.1.6, 8.3.1.5.2.2
Unit contacts in exploratory boreholes	8.3.1.4.2.1
Fault recharge rate	8.3.1.2.2.4.9b
Fault zone hydraulic characteristics	
Characteristics of hydrologic flow in fault zones	8.4.2.4.1, 8.4.2.4.2, 8.4.2.4.3
Saturation of alluvium	8.3.1.2.2.1.3
Surface water supply	8.2.1.2.1.2.1

monitoring at specific sealing locations, which will not become available until the excavation is well developed. Similarly, the site-specific characterization of hydraulic conductivity and saturation of the alluvium adjacent to shaft locations constitutes a set of determinations important to the calculation of water inflow into the shafts during and following precipitation events. The surficial geology surrounding the shaft locations will be characterized. The integration of the hydraulic measurements with these activities will be important to addressing the potential for water to be directed towards the shafts.

Several major exploratory drifts will focus on the fault zones and the hydrologic investigations are pertinent to quantify the amount of water (if any) that may enter the underground facility. The effects of anisotropic flow within the fault, characterization of the geochemistry of waters contained in the fault zone, and the effects of overlying alluvial sediments on the recharge of the fault zones will also be considered. Additional concerns regarding sealing, containment, and dispersal of waters from fault zones, and possibly perched water, intersected at depth will be considered in evaluating the field observations. The true importance of these concerns will ultimately rest upon the locations of the zones encountered, the number of zones intersected, the rate and frequency of flow within the fault zones, and the ability to disperse the water by infiltration to below the repository horizon.

Table 8.3.3.2-8. Seal material and emplacement environment properties needed

Property	Modifiers	Tentative property goal	Needed confidence	Current confidence	Expected property value	SCP section
Shaft and ramp fill properties						
- Saturated hydraulic conductivity		1×10^{-2} cm/s	High	Low	1×10^{-2} to 1×10^{-6} cm/s	8.3.3.2.2.1.2
- Gradational analyses, angle of internal friction, compressibility		To be determined through design trade-off studies	High	Low	NA[a]	8.3.3.2.2.1.1
Grade of emplacement drifts and dimensions	In repository	1 to 10%	NA[a]	High	1 to 10%	8.3.2.5.8, 8.3.2.2.7
Casing location and condition for exploratory boreholes	All boreholes in categories A and B[b]	Location of casing to ±5 m. Conditions determined by logging and drilling records	High	Medium	See Fernandez and Freshley (1984)	8.3.3.2.4
Thermal effects of water saturation and desaturation		Will balance out over the life of the repository	Medium	Low	Expect will balance out over life of repository	8.3.4.2.4
Intersection of emplacement boreholes and faults		No intersections	High	Low	Expect no intersections	8.3.1.4.2.3, 8.3.1.17.4.7
Maximum temperature at seal locations	Upper portion of shaft	<90°C	High	Low	<90°C	8.3.2.2.6
	At repository horizon around shaft	To be determined through design trade-off studies	TBD[c]	TBD	<115°C	8.3.2.2.6
	At selected drift locations in repository horizon	To be determined through design trade-off studies	TBD	Low	<150°C	8.3.2.2.6
	Calico Hills unit in boreholes below the repository	<90°C	High	Low	<90°C	8.3.2.2.6

[a]NA = not applicable.

[b]Category A boreholes represent potential pathways to the accessible environment. Category B boreholes are not potential pathways to the accessible environment but because of their proximity to the repository boundary are currently planned to be sealed. These boreholes are identified in Table 8.3.3.2-1a.

[c]TBD = to be determined.

Adequacy of data--on seal materials properties. The properties of the shaft and ramp fill are identified in Table 8.3.3.2-8. Additional needed information on seal materials is outlined in Table 8.3.3.2-6, which indicates potentially important material properties of concern for sealing components. These information needs and the required testing will be modified, if necessary, as the seal design requirements are refined.

Adequacy of data--emplacement concerns. Information needs on various operations including the removal of the liner and the emplacement of seal components are evaluated for the preferred and secondary options of seal components in Tables 8.3.3.2-9a and 8.3.3.2-9b respectively. The following evaluations assume that specific seal components would be placed to provide additional assurance that performance goals can be achieved. Specific emplacement concerns are raised, and the needed confidence and current confidence that the emplacement operations can be achieved are identified. The material properties of concern are then identified. A summary of the adequacy of the data is presented below.

In general, there is a high level of confidence that liners can be removed, that keyways can be constructed, that seals composed of either earthen or cementitious materials can be emplaced, and that existing laboratory or field methods for monitoring quality control or defining performance or index properties are available and adequate. The material properties of concern for grouts include cement particle size, the hydraulic conductivity of cement, and the hydraulic conductivity of welded tuff. The properties for cementitious materials include hydraulic conductivity, particle size, density, heat of hydration, slump, and setting time. The properties for earthen materials include density, moisture content, particle gradation, and swelling potential. These properties will be characterized by laboratory testing.

During repository construction and operation, fines may enter the floor and could reduce the floor hydraulic conductivity. This would reduce floor infiltration capacity at the repository horizon. Laboratory testing is required to identify the effects of solids in water (particle size and gradation) on reducing hydraulic conductance. The concerns to be addressed include the potential for fines to migrate as a function of particle size, particle gradation, hydraulic potential, and infiltration rate. This testing may be performed in conjunction with the sand-bed test as described subsequently.

Special concerns regarding grouting or the use of cut-offs are currently expected to be addressed through subsequent advanced conceptual design trade-off studies. Nevertheless, either grout curtains or earthen dams may need to be designed and constructed to cut off flow through the modified permeability zone around shaft seal components. These possibilities will be considered if low permeability zones with favorable fracture frequencies, orientations, and apertures cannot be located, or if sufficient sump/floor drainage capacity in specific areas at the repository horizon does not exist. In these instances, a postconstruction emplacement test might be required that would test the effectiveness of the grout curtain and confirm that hydrologic performance can be achieved through a suitable grout pattern, the use of grout pipes, and the selection of grout injection pressures.

Table 8.3.3.2-9a. Emplacement concerns for the preferred sealing options (page 1 of 4)

Design options	Tentative design goals	Emplacement issues and uncertainties	Needed confidence that the operation can be achieved	Current confidence that the operation can be achieved	Material properties of concern
Anchor-to-bedrock plug	Limit surface waters entering shaft to 1,700 m^3/yr from 0 to 500 yr and 23,000 m^3/yr at the end of the sealing period (1,000 yr)	Can the liner be removed before plug placement without propagating the modified permeability zone (MPZ) outward at the plug location?	Medium	High	Unconfined compressive strength of the liner
		- Can the liner be drilled and split by one of the drill and blast or hydraulic splitter methods?	High	High	Unconfined compressive strength of the liner
		- Can the broken liner be mucked to the surface?	Low	High	NA[a]
		Can a keyway be excavated before plug construction?	High	High	Unconfined compressive strength of the welded tuff
		- Can the keyway in the welded tuff be excavated?	High	High	Unconfined compressive strength of the welded tuff
		- Can the keyway excavation be performed without propagating fractures outward?	High	High	Tensile strength, unconfined compressive strength, far-field in situ stress
		- Can rock be removed to the surface?	High	High	NA

Table 8.3.3.2-9a. Emplacement concerns for the preferred sealing options (page 2 of 4)

Design options	Tentative design goals	Emplacement issues and uncertainties	Needed confidence that the operation can be achieved	Current confidence that the operation can be achieved	Material properties of concern
Anchor-to bedrock plug (continued)	Limit surface waters entering shaft to 1,700 m^3/yr from 0 to 500 yr and 23,000 m^3/yr at the end of the sealing period (1,000 yr) (continued)	Can grout be placed effectively by the selection of a suitable grout pattern, the use of grout pipes, and the selection of grout injection pressures?	Low to high	Medium	Cement particle size, hydraulic conductivity of tuff, hydraulic conductivity of cement
		Can grout workability be ensured during placement in the in situ moisture and temperature environment?	High	High	Setting time, slump, viscosity
		Cementitious plug materials			
		Can the material be placed with specified properties to form an effective hydrologic barrier?	High	High	Sieve analysis, density, heat of hydration, slump, setting time
		Can shrinkage and temperature effects due to hydration significantly alter the interface zone?	Low to high[b]	Medium to high[b]	Heat of hydration, thermal conductivity, specific heat, thermal expansion
		Can workability be ensured during placement to eliminate either premature setting or particle segregation?	High	High	Setting time, slump, viscosity

Table 8.3.3.2-9a. Emplacement concerns for the preferred sealing options (page 3 of 4)

Design options	Tentative design goals	Emplacement issues and uncertainties	Needed confidence that the operation can be achieved	Current confidence that the operation can be achieved	Material properties of concern
Exploratory boreholes	Reduce potential for flow below the repository horizon to 1 percent of the total flow through the area within the repository perimeter	Can the casing be removed and a plug emplaced in an exploratory borehole?	High	Medium to high[c]	NA
Single dam or single bulkhead with settlement					
Emplacement drifts	Retain a portion of the ground-water inflow near source by providing adequate storage volume and drainage capacity	Can grout be placed effectively by the selection of a suitable grout pattern, the use of grout pipes, and the selection of grout injection pressures?	Low to high[b]	Medium	Cement particle size, hydraulic conductivity of fractures in welded tuff, hydraulic conductivity of cement
	Limit flow through dam to 47 m^3/yr from 0 to 300 yr and 220 m^3/yr to the end of the sealing period (500 yr)	Can grout workability be ensured during placement in the in situ moisture and temperature environment?	High	High	Setting time, workability, slump, viscosity
	Retain a portion of the ground-water inflow near the source by providing adequate storage volume and drainage capacity	Can fines be removed from the floor or controlled from entering the fracture system to reduce silting potential?	High	Low[d] to high	Particle gradation of fines, hydraulic conductivity of fractures in welded tuff

Table 8.3.3.2-9a. Emplacement concerns for the preferred sealing options (page 4 of 4)

Design options	Tentative design goals	Emplacement issues and uncertainties	Needed confidence that the operation can be achieved	Current confidence that the operation can be achieved	Material properties of concern
		Earthen plug materials			
Emplacement drifts (continued)		Can pneumatic, hydraulic, or hand placement methods be used to emplace an earthen material with specified material properties (e.g., gradation, density, high swelling capacity) to form an effective hydrologic barrier?	High	High	Density, moisture content, particle gradation, swelling potential
General shaft backfill	Reduce potential for water and air flow	Can the shaft fill be emplaced by hydraulic, pneumatic, or hand placement methods to achieve specified properties (e.g., density, swelling capacity, and permeability)?	Medium to high[c]	High	Density, moisture content, particle gradation
Permimeter drifts or mains	Promote drainage through drift floor upgradient from dam by limiting leakage through the dam or bulkhead to 10% of the drainage capacity of the drift floor upgradient from the dam, i.e., <200 m^3/yr	Can a continuous grout structure be achieved by redrilling holes many times and grouting without affecting the sump drainage capacity?	High	Medium	Workability, viscosity, cement particle size
		Can a compacted, low permeability backfill be emplaced by hydraulic, pneumatic, or hand placement methods with specific properties (e.g., optimum moisture content, density, swelling capacity and low density)?	High	Medium	Density, moisture content, particle gradation
		Can cracks due to shrinkage or thermal effects create significant water paths?	Low to high[b]	Low to high[b]	Hydraulic conductivity of fractures in welded tuff

[a]NA = not applicable.
[b]Needed confidence depends on site conditions.
[c]Depends on whether shaft fill is a redundant seal component.
[d]In excavating the sump, it may be beneficial to use a nonexplosive demolition agent (NEDA) in restoring the floor to the original excavation quality.

Table 8.3.3.2-9b. Emplacement concerns for the secondary sealing options (page 1 of 5)

Design options	Tentative design goals	Emplacement issues and uncertainties	Needed confidence that the operation can be achieved	Current confidence that the operation can be achieved	Material properties of concern
Station and shaft plugs	Limit surface and subsurface waters entering the underground facility to 1,000 m^3/yr (station plug) from 0 to 500 yr and 14,000 m^3/yr at the end of the sealing period (1,000 yr)	Can the liner be removed before plug placement without propagating the modified permeability zone (MPZ) outward at the plug location?	High	High	Unconfined compressive strength of the liner
		- Can the liner be drilled and split by one of the drill and blast or hydraulic splitter methods?	Low	High	Unconfined compressive strength of the liner
		- Can the broken liner be mucked to the surface?	Low	High	NA[a]
		Can a keyway be excavated before plug construction?	High	High	Unconfined compressive strength of welded tuff
		- Can the keyway in the welded tuff be excavated?	High	High	Unconfined compressive strength of welded tuff
		- Can the keyway excavation be performed without propagating fractures outward?	High	High	Tensile strength, unconfined compressive strength, far-field in situ stress
		- Can rock be removed to the surface?	High	High	NA[a]
		Can grout be placed effectively by the selection of a suitable grout pattern, the use of grout pipes, and the selection of grout injection pressures?	High	Medium	Cement particle size, hydraulic conductivity of tuff, hydraulic conductivity of cement

Table 8.3.3.2-9b. Emplacement concerns for the secondary sealing options (page 2 of 5)

Design options	Tentative design goals	Emplacement issues and uncertainties	Needed confidence that the operation can be achieved	Current confidence that the operation can be achieved	Material properties of concern
Station and shaft plugs (continued)		Can grout workability be ensured during placement in the in situ moisture and temperature environment?	High	High	Setting time, slump, viscosity
		Cementitious materials			
	Provide structural support of shaft backfill (station and shaft plugs in shaft) if necessary	Can the materials be placed with specified properties to form an effective hydrologic barrier?	High	Medium	Density, compressive strength, permeability
		Can shrinkage and temperature effects due to hydration significantly alter the interface zone?	Low to high	Medium to high	Heat of hydration, thermal conductivity, specific heat, thermal expansion
		Can workability be ensured during placement to eliminate either premature setting or particle segregation?	High	High	Setting time, workability, slump, viscosity
		Earthen materials			
		Can pneumatic, hydraulic, or hand methods be used to emplace an earthen material with specified material properties (e.g., gradation, density, high swelling capacity) to form an effective hydrologic barrier?	High	Medium	Density, moisture content, particle gradation
Double bulkhead (no settlement)					
Emplacement drifts	Retain inflow between two bulkheads by providing adequate storage volume and drainage capacity	Can a keyway be excavated before seal construction?	High	High	Unconfined compressive strength of welded tuff

Table 8.3.3.2-9b. Emplacement concerns for the secondary sealing options (page 3 of 5)

Design options	Tentative design goals	Emplacement issues and uncertainties	Needed confidence that the operation can be achieved	Current confidence that the operation can be achieved	Material properties of concern
Emplacement drifts (continued)		- Can the keyway in welded tuff be excavated?	High	High	Unconfined compressive strength of welded tuff
	Limit flow through bulkhead to 24 m^3/yr/bulkhead from 0 to 300 yr and 110 m^3/yr/bulkhead to the end of the sealing period (500 yr)	- Can the keyway excavated be performed without propagating fractures outward?	High	High	Tensile strength unconfined compressive strength, far-field in situ stress
		- Can the rock be removed to the surface?	High	High	NA
		Can grout cements be placed effectively by the selection of a suitable grout pattern, the use of grout pipes, and the selection of grout injection pressures?	High	Medium	Cement particle size, hydraulic conductivity of cement
		Can grout workability be ensured during placement in the in situ moisture and temperature environment?	High	High	Setting time, workability, slump, viscosity
		Cementitious materials			
		Can the material be placed with specified properties to form an effective hydrologic barrier?	High	Medium	Density, compressive strength, and permeability
		Can shrinkage and temperature effects due to hydration significantly alter the interface zone?	High	Low	Heat of hydration, thermal conductivity, specific heat, thermal expansion

Table 8.3.3.2-9b. Emplacement concerns for the secondary sealing options (page 4 of 5)

Design options	Tentative design goals	Emplacement issues and uncertainties	Needed confidence that the operation can be achieved	Current confidence that the operation can be achieved	Material properties of concern
Emplacement drifts (continued)	Limit flow through bulkhead to 24 m^3/yr/bulkhead from 0 to 300 yr and 110 m^3/yr/bulkhead to the end of the sealing period (500 yr) (continued)	Can workability be ensured during placement to eliminate either premature setting or particle segregation during placement?	High	Medium	Setting time, workability, slump, viscosity
		Earthen materials			
		Can pneumatic, hydraulic, or hand placement methods be effectively used to emplace an earthen material with specified material properties (e.g., gradation, density, high swelling capacity) to form an effective hydrologic barrier?	High	High	Density, moisture content, particle gradation
		Can cracks due to shrinkage or thermal effects create significant water paths?	Low to high[b]	Low	Strain parameters - Young's modulus - tangent modulus Poisson's ratio, cohesion foliation angle
Backfilled sump	Retain ground-water inflow near source	Can fines be removed from the floor to reduce silting potential?	High	Low to high	Particle gradation of fines, hydraulic conductivity of welded tuff
Plug in a horizontal emplacement hole	Limit ground-water inflow past plugs to 12 m^3/yr from 0 to 300 yr and 56 m^3/yr at the end of the sealing period (500 yr)	Can the material be placed with specified properties?	High	High	Density, compressive strength, permeability

Table 8.3.3.2-9b. Emplacement concerns for the secondary sealing options (page 5 of 5)

Design options	Tentative design goals	Emplacement issues and uncertainties	Needed confidence that the operation can be achieved	Current confidence that the operation can be achieved	Material properties of concern
Plug in a horizontal emplacement hole (continued)	Limit ground-water inflow past plugs to 12 m^3/yr from 0 to 300 yr and 56 m^3/yr at the end of the sealing period (500 yr) (continued)	- Can shrinkage and temperature effects due to hydration be controlled by testing to reduce separation at the interface zone?	High	Low	Heat of hydration, thermal conductivity, specific heat, thermal expansion
		- Can workability be ensured during placement to eliminate either premature setting or particle segregation during placement?	High	High	Workability setting time, slump, viscosity
Channel in backfilled room	Channel ground-water inflow away from waste package, dependent on hydraulic conductivity of channel fill material, at the following flow rates: <2,000 m^3/yr (<1 gal/min) 2,000 to 20,000 m^3/yr (1-10 gal/min) 20,000 to 2 x 10^5 m^3/yr (10-100 gal/min)	Can backfill be emplaced in channel subject to quality control testing of specified gradations to eliminate the potential for silting?	High	High	Particle gradation of backfill
	Limit ground-water inflow past plugs to 12 m^3/yr from 0 to 300 yr and 56 m^3/yr at the end of the sealing period (500 yr)	Can grout be injected at the interface zone to reduce conductivity?	High	Medium	Cement particle size, hydraulic conductivity of cement

[a]NA = not applicable.
[b]Needed confidence depends on site condition.

A sealing component with a tight, low-permeability interface may need to be designed and constructed so that either temperature and hydration effects will be controlled for cementitious materials during emplacement or shrinkage will be controlled for earthen materials during placement. In this instance, consideration may be given to field testing to confirm the performance of the interface zone.

State of-the-art considerations. The following considerations are important in evaluating the need for in situ tests on sealing components prior to license application:

1. Current design requirements for hydraulic conductivity particularly in the case of general shaftfill (10^{-2} cm/s) or for seals (10^{-5} to 10^{-4} cm/s) are expected to be easily achievable with current emplacement methods for cementitious or earthen materials.

2. Current information indicates that the hydrologic properties of the interface zone are not significant in achieving the hydrologic performance goals for the seal system considering unsaturated flow.

3. While the range of potential host-rock properties is significant, it is likely that seals could be located in low permeability zones with minimal modified permeability zone (MPZ) effects. Current designs that would utilize grouting, and keyways may not be required.

4. Depending in part upon the inflow observed at the repository horizon, floor and sump infiltration rates may be quite sufficient in eliminating the potential for lateral flow at the repository horizon and would eliminate the need for earthen dams or bulkheads at this horizon.

5. Laboratory methods are available to evaluate important index properties used for quality control during emplacement and are planned as discussed subsequently.

6. Several seals emplacement methods are currently available and alternative methods are proposed to accommodate varying site conditions. Existing conceptual designs are not dependent on specific emplacement methods.

7. Additional design information on the underground facility is necessary for the selection of the specific seal locations and emplacement methods that would be available after construction startup.

Several of these considerations are elaborated in the following paragraphs.

In achieving the performance goals, it is currently possible to specify either cementitious or earthen materials with conductivities that are several orders of magnitude lower than the current hydrologic design requirements (10^{-5} to 10^{-4} cm/s) for the preferred sealing options. Typical concrete hydraulic conductivities of less than 10^{-8} to 10^{-6} cm/s are currently achievable, and special concretes with hydraulic conductivities less than 10^{-10} cm/s have been reported (Mather, 1967). For earthen materials, low

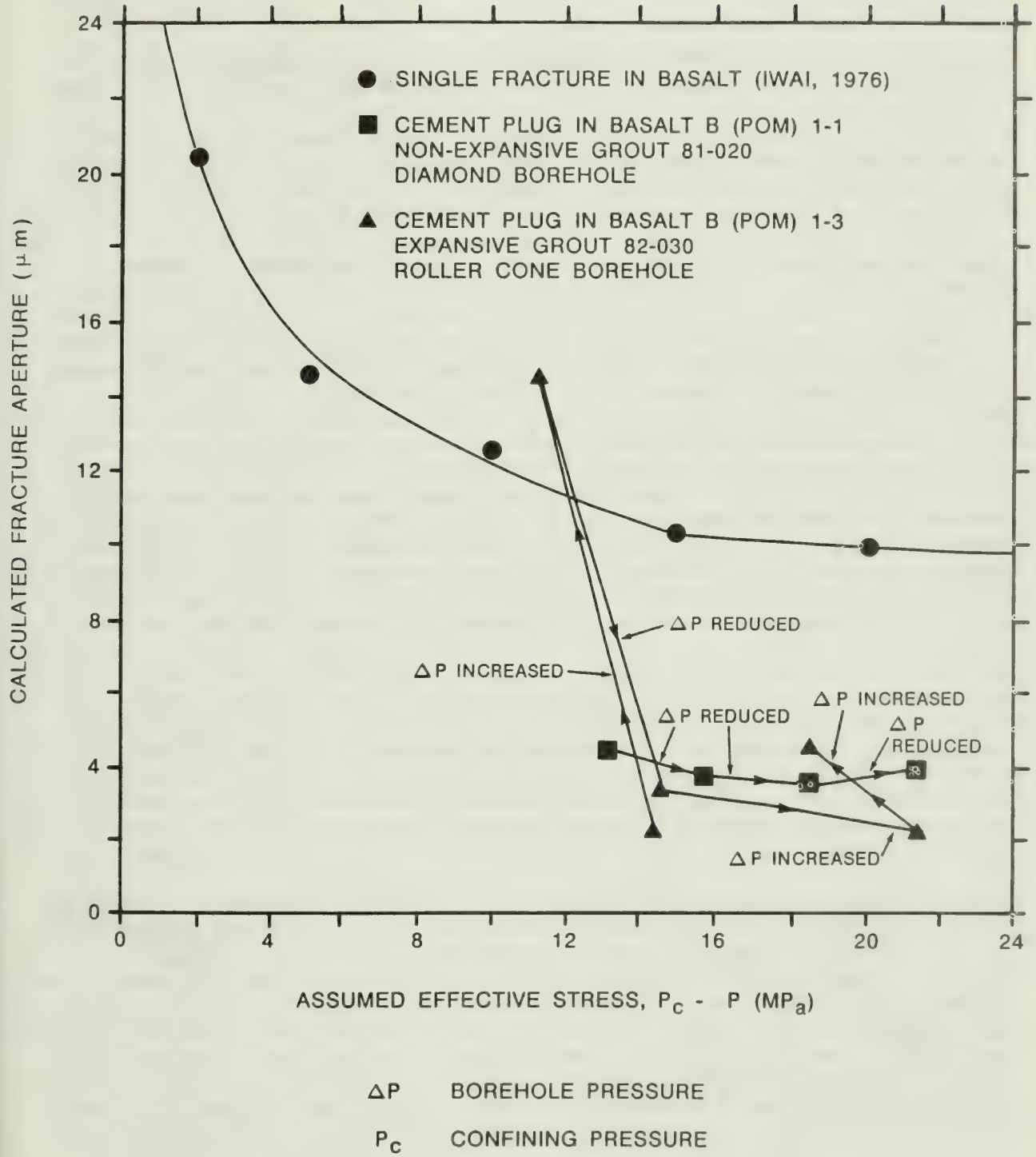
hydraulic conductivities may be achieved by increasing the content of clay or silt. For example, mixtures using kaolinite clay have conductivities as low as 10^{-8} cm/s, while mixtures with bentonite can be as low as 10^{-12} cm/s (Fernandez et al., 1987).

Previous investigations have evaluated the properties of the interface zone in anhydrite and basalt (Lingle and Bush, 1982; Kelsall et al., 1984). The properties of an anhydrite-interface zone were investigated in laboratory tests. A 48-cm long by 20-cm diameter cement plug was placed in a borehole drilled in the laboratory in a block of anhydrite (Kelsall et al., 1984). The borehole was drilled, and the plug placed in a custom-built pressure vessel that allowed simulation of the in situ conditions, such as overburden stress, bit pressure, and mud pressure. After the plug was cured, a flow test was performed using a differential-fluid pressure of 13.8 MPa (2,000 psi). Dye penetrant was introduced in the permeant to determine the flow path. Finally, after the flow test was completed, the sample was removed from the pressure vessel and sectioned for examination of the interface. Assuming the flow occurred across the cross-sectional area of the cement plug, the equivalent permeability was found to be of the order of 10^{-7} cm/s. Examination of the sectioned plug and the dye penetration revealed clearly that the flow had been concentrated at the interface in a much smaller area than that arbitrarily assigned for calculation of equivalent permeability.

A subsequent test was performed in basalt (Lingle and Bush, 1982). In analyzing the data from basalt, an assumption can be made that flow occurs through the interface zone which behaves like a smooth-wall fracture. Assuming the cubic law applies, an equivalent-smooth-wall fracture aperture may be calculated and plotted as a function of effective stress (the difference between confining pressure and pore pressure) as indicated in Figure 8.3.3.2-4.

The results support the theory that the interface zone behaves like a fracture in that at low effective stress levels, the interface is "open" and exhibits high conductivity. At higher stress levels, the interface becomes "closed" and exhibits a much lower conductivity that is independent of effective stress level. Further evidence is provided by comparing the results with flow tests on a single fracture in basalt (Iwai, 1976) as illustrated in the figure. An equivalent smooth-wall aperture of four micrometers is indicated and would correspond to a "tight" flow zone at high effective stress.

An experiment on a borehole seal in welded tuff has been reported by Daemen et al. (1983). A rock specimen 31 cm long by 15 cm in diameter was installed in a permeameter and loaded axially and laterally with confining stresses ranging from 7 to 20 MPa and axial stresses ranging from 8 to 23 MPa. A coaxial hole (2.5 cm in diameter) was then drilled from each end of the specimen leaving a rock bridge in the center. A differential pressure was applied and flow measurements were performed. After these initial flow measurements were performed, the rock bridge was drilled out and replaced by a cement plug. The plug was then tested under a similar set of total stress and pore pressure conditions. Daemen et al. (1983) expressed the conductivity of the plug as an equivalent conductivity for flow through plug and interface zone. The reported values ranged from 10^{-13} to 10^{-10} cm/s. If the flow is assumed to occur through a smooth-wall "crack" at the plug perimeter, an



ΔP BOREHOLE PRESSURE

P_c CONFINING PRESSURE

Figure 8.3.3.2-4. Comparison of borehole plug test with experimental data for fractured basalt. Data for plug tests from Lingle and Bush (1982).

equivalent smooth-wall fracture aperture of 0.5 to 5 micrometers is calculated, which is similar to the calculated value from the test in basalt.

While application of these results to the emplacement of large-scale seals in welded tuff and the need for future laboratory testing to confirm the interface-zone flow performance is a concern, it is likely that a tight interface zone will be achieved for seals emplaced in welded tuff. In this case, the conductance of the interface zone may not be the controlling factor when compared with the conductance of the plug or the surrounding modified permeability zone.

Modified permeability zone studies (Case and Kelsall, 1987) have examined the potential range of hydrologic properties for shafts excavated in welded tuff (the increase in permeability and radial extent of the damaged zone). Tentative design goals (Fernandez et al., 1987) assumed worst case conditions: their assumptions were that the hydraulic conductivity of the host rock is 10^{-2} cm/s, and that the increase in conductivity of the MPZ is 60 times the host rock conductivity. These conditions assume that deformations due to stress relief across fractures are inelastic, that a 1.0-m-wide blast-damage zone has formed, and that changes in fracture conductivity are sensitive to stress. Further, the calculations neglected the role of artificial support in restricting rock deformations. These rock conditions could necessitate the design of a keyway, and treatment of the MPZ if the surrounding host rock conductivity (10^{-2} cm/s) is at the high end of the range of conductivities for welded tuff. However, a location will likely be found for key seals that would have more favorable rock properties (e.g., host rock conductivity is low, rock deformations are elastic, blast damage zone is thin, and fracture conductivity is insensitive to changes in stress). For these conditions, the host rock conductivity might be several orders of magnitude lower and the conductivity in this zone might increase by a lower factor. Treatment of the MPZ by the construction of a keyway or grouting may not be required for these rock conditions.

The drainage through sump areas at the bottom of the shafts or through the drift floor at the repository horizon have been calculated by Fernandez et al. (1987) and compared to anticipated flow rates. It was found that if a sump in a shaft is constructed below the repository horizon, adequate drainage capacity would exist to dissipate flows without water entering the repository. If water were to enter the repository from shafts, it would flow to the lowest part of the repository, which has an estimated drainage capacity of 32,000 m^3/yr (assuming vertical emplacement and a bulk rock hydraulic conductivity of 10^{-5} cm/s). This would be quite sufficient to drain anticipated flow rates. In individual drifts, it is expected that the drainage capacity of the flow will far exceed the anticipated flow rates to the underground facility.

The flow rates for anticipated conditions ranged from 40 to 60 m^3/yr for the entire underground facility. The floor drainage capacity of a single room is approximately 6,000 m^3/yr assuming the saturated conductivity of the tuff is 10^{-5} cm/s. This indicates that the expected inflow is much smaller than the potential drainage capacity.

Shaftfill or backfill can be emplaced using mechanical or pneumatic methods. In the former case, the crushed tuff would be transported by conveyers and emplaced by load-haul-dump vehicles and small bulldozers. As

necessary, the material can be compacted with smooth-drum rollers, hand-held tampers or vibratory compactors, or by repeated passes by the emplacement equipment (Hilf, 1975). Effective compaction of sand and gravel has been obtained using vibratory rollers (Terzaghi and Peck, 1967). The material is spread in layers 12 to 14 in. thick and two to four passes of the roller are used. Moisture control is not necessary. In limited areas, self-propelled, hand-operated vibratory compactors have also been found useful.

Pneumatic emplacement can handle earthen materials up to three inches in size, which can be transported directly from the surface. Methods used for pneumatic backfilling of abandoned mines are discussed by Eby (1981). For earthen materials, greater compaction can be achieved in materials containing a wide range of grain sizes (well graded) than in more uniform materials.

Emplacement methods are also available for cementitious materials. Auld (1983) presents information on important construction aspects for batching and transporting concrete, placement methods for eliminating thermal and shrinkage effects, and grouting procedures. Auld (1983) also presents several case histories in which the effectiveness of seal emplacement (reduced flow rate as a function of time) was demonstrated. In one instance, at a mine in England, Auld (1983) reports that a low heat of hydration mix, incorporating a cement replacement material was used to construct an emergency plug that resulted in a one hundred-fold reduction in flow rate.

Possible in situ sealing tests

The process to develop in situ seals tests was described above. Four steps were defined: (1) evaluation of site and seal materials properties, (2) evaluation of the adequacy of these properties including a discussion of the current state of the art, (3) definition, evaluation, and selection of in situ tests of seal components, and (4) detailed definition and design of specifics of field tests. Preliminary evaluations supporting the first two steps have been completed, and some of the evaluations of step 3 are completed. However, before step 4 can be completed, additional information will be required from site characterization activities and from an evaluation of the role that the sealing subsystem plays on the overall repository performance (step 3). Nevertheless, the initial evaluations in step 3, as supported by the assessments performed in steps 2 and 3, do indicate several areas in which field tests may be performed to reduce uncertainties in seal performance. These are verification of emplacement techniques and seal behavior under anticipated and unanticipated hydrogeologic conditions. Examples of potentially appropriate tests are siltation-infiltration tests, borehole seal tests, and a shaft seal test.

The definition of the seals tests will be based in part on some of the hydrologic information obtained early in site characterization and data may include the rate of flow of water, degree of fracturing of the rock mass, fracture orientation, fracture interconnectivity, etc. The test definition is planned to be completed in time to conduct needed experiments before license application.

Once in situ tests have been defined, test locations will be selected so other planned or ongoing tests will not be disturbed and also so other tests will not disturb the sealing test. Evaluations will also be made to ensure

that the quantity of water proposed for use in the tests will not significantly increase uncertainties relative to postclosure performance.

If it is determined that sealing-related testing influences other tests or leads to postclosure performance uncertainties, consideration will be given to conducting the tests in an alternative location, such as G-tunnel on the Nevada Test Site. A study plan will be prepared to support the in situ test program for seals after detailed concepts for testing are developed.

It is important to emphasize that many tests supporting the sealing program will be performed within the ESF (e.g., the hydrologic tests defined in Table 8.3.3.2-7). Should other tests be indicated as a result of these tests and other activities, sufficient flexibility exists for expanding the ESF to accommodate additional appropriate tests.

8.3.3.2.2.4 Application of results

The information obtained in this information need will be provided to the reference Yucca Mountain Project data base and will be used in Information Needs 4.4.10 (technology for seals emplacement, Section 8.3.2.5.10), 1.12.3, and 1.12.4.

8.3.3.2.3 Information Need 1.12.3: Placement method for seals for shafts, drifts, and boreholes

Technical basis for addressing the information need

The technical basis for addressing the information need is discussed below by first identifying the contents of related sections of the SCP and other documents. Needed parameters are then described. The logic for the technical activities is described and planned design activities are identified.

Link to the technical data chapters and applicable support documents

Seals may be required to limit ground-water flow through shafts, drifts, or boreholes that could contribute to release of radionuclides from the repository. These seals, if required, must be designed to be emplaced using adequately established technology and must be emplaced so that seal performance is acceptable. Once the reference designs are selected as part of Information Need 1.12.4, data required to select appropriate placement methods will be obtained.

Information that will be required in selecting a suitable placement procedure for sealing components includes the design of the repository, conditions of man-made and natural penetrations that must be sealed and the required properties of the sealing materials/systems. Design of the repository is presented in Section 6.2 of the SCP and in the SCP-CDR (SNL, 1987). Knowledge of the conditions to be encountered in the underground facility, the shafts, and ramps will be obtained through observations at the time of

the excavation of the exploratory shaft facility. The design portion of the Yucca Mountain Project repository seal program uses the approach that a range of hydrogeologic conditions may be encountered as the repository is developed. These variable conditions could, therefore, require variable placement options. The general descriptions of water entering the exploratory shafts and the exploratory shaft facility will provide an increased data base on water-producing zones that may require sealing and hence, consideration of the appropriate placement technique.

Data on borehole conditions are currently being recorded. Borehole conditions are briefly described in Chapter 6 of the SCP.

Parameters

Several properties of candidate seal materials are directly affected by placement methods and conditions. Conversely, the selection of a feasible emplacement method may be influenced by properties of the material. Data needed to address this information need include the available placement or construction methods for proposed seal components and those properties of seal materials that affect or are affected by emplacement.

For earthen materials (clays, rockfill), these properties are

1. Density-water content relation.
2. Particle gradation.
3. Hydraulic conductivity related to density.
4. Swelling capacity related to density.

For cementitious materials, these properties are

1. Density.
2. Heat of hydration.
3. Slump, viscosity.
4. Workability.
5. Set time and working time.
6. Maximum particle size of aggregate phases.

The data represented in the preceding list are those variables that can be modified to accommodate the placement strategy to be used for the sealing component. Because multiple placement strategies will be proposed to accommodate varying site conditions, no site parameters will be required to establish the appropriate placement methods. Site conditions as encountered will focus on the appropriate placement method. Design information on the underground facility and existing boreholes is also necessary to select the appropriate placement method. Laboratory analyses will be performed as part of Study 1.12.2.1 (Section 8.3.3.2.2.1) under Information Need 1.12.2 to define the properties of earthen and cementitious-based materials identified previously.

Logic

For granular materials (e.g., clays, crushed rock), the method and degree of compaction may have a strong effect on density and porosity, hydraulic conductivity, and swelling pressure. The required in situ properties

may influence the selection of emplacement method, principally according to the degree of compaction necessary. Selection may also be influenced by the gradation and moisture content of the material. For example, pneumatic methods may be limited to certain gradation and moisture ranges. Performance of cementitious materials may be affected by the method of consolidation, the presence of free water, and temperature during emplacement and curing. Selection of placement methods will be influenced by properties such as the heat of hydration, working time, harshness, and viscosity. For example, the heat of hydration of a concrete mix may limit the thickness of any lift that can be emplaced to prevent undue thermal stresses in the seal zone.

There are no planned design activities identified for this information need. Any trade-off design activities evaluating the appropriate placement method will be performed as part of the advanced conceptual design or the license application design (Information Need 1.12.4, Section 8.3.3.2.4). Development of properties of earthen and cementitious-based materials will be obtained as part of Information Need 1.12.2 (Section 8.3.3.2.2).

8.3.3.2.3.1 Application of results

The data obtained in this information need will be used directly in deriving practical seal designs (Information Need 1.12.4). The data will contribute to other information needs addressing design and performance issues. The two information needs are 1.11.7, reference postclosure underground designs (Section 8.3.2.2.7), and 4.4.9, technology for underground facilities (Section 8.3.2.5.9).

8.3.3.2.4 Information Need 1.12.4: Reference design of seals for shafts, drifts, and boreholes

Technical basis for addressing the information need

The technical basis for addressing the information need is discussed below by first identifying the contents of related sections of the SCP and other documents. Needed parameters are then described. The logic for the technical activities is described and planned design activities are identified.

Link to the technical data chapters and applicable support documents

This information need will provide the seal design that will become part of the overall repository design. The seal design, therefore, is described in Section 6.2, current repository design description. A further description of the seal component design will be given in the SCP-CDR (SNL, 1987). As part of this information need the seal design, which is based on design requirements, will be developed.

Parameters

To develop the seal design, site and repository design information is required. The parameters needed for design are defined in the parameters subsection of Information Need 1.12.1, Section 8.3.3.2.1. Using the designs provided in this information need description, the appropriate materials (Information Need 1.12.2, Section 8.3.3.2.2) and placement methods (Information Need 1.12.3, Section 8.3.3.2.3) will be selected.

Logic

The seal design effort integrates the parameters from Information Need 1.12.1. If seals are found to be necessary, the design requirements for the seal system can be developed. The design requirements are those properties that the seal system must attain, such as low overall hydraulic conductivity, to meet regulatory guidelines for radionuclide releases.

Design requirements will also specify the requirements for materials to be used in the seals or seal components. These will include the properties needed to attain seal performance requirements. These design requirements form a basis for materials testing (Information Need 1.12.2) and for selecting materials to be included in the seal designs. The placement technology study to be performed as part of the trade-off studies associated with the advanced conceptual design activities will provide additional input to the design regarding suitable construction methods and their effects on seal performance. Thus, the design study and the materials and emplacement studies interface closely and require a degree of iteration between design requirements and materials properties testing.

Both of the design activities defined below are divided into three areas: define design requirements, perform trade-off studies, and develop seal designs.

8.3.3.2.4.1 Design Activity 1.12.4.1: Development of the advanced conceptual design (ACD) for sealing

8.3.3.2.4.1.1 Design Subactivity 1.12.4.1.1: Define subsystem design requirements

Objectives

The objective of this subactivity is to develop design requirements that will assist the designer in the development of sealing components.

Description

Currently, the following tasks will be performed to support the advanced conceptual design:

1. Define sealing components.

2. List state and local regulations to establish the basis for design.

3. Develop functional requirements for the sealing subsystem, including the subsystems role in ensuring long-term waste containment and isolation.

4. Define the performance criteria for the sealing system to establish the level of performance required of the sealing system.

5. Identify the interfaces between the sealing system and other systems.

6. Define constraints in limitations placed on the sealing system or on other systems by the sealing system.

7. Describe the design-basis assumptions (if any) to be used in designing the sealing system.

8.3.3.2.4.1.2 Design Subactivity 1.12.4.1.2: Perform trade-off studies to support advanced conceptual design development

Objectives

The objective of this subactivity is to provide technical justification for the selection of specific design options.

Description

The primary focus of the advanced conceptual design (ACD) work will be the resolution of design and engineering issues through the use of engineering tradeoff studies. These tradeoff studies would

1. Evaluate the potential suitability of gradations for the shaft and drift fill. If materials from the exploratory shaft are unavailable before the development of the design, only an analytical assessment of shaft settlement will be performed using a simple consolidation theory and available material properties.

2. Evaluate strategies for dissipating water at the floor of ramps and drifts.

3. Evaluate strategies for sealing discrete, water-producing fault or fracture zones encountered in horizontal emplacement holes and drifts.

4. Evaluate the need for settlement plugs by determining the consolidation behavior of various shaft fills and the subsequent consequence if no plugs are emplaced.

5. Assess the effectiveness of sealing components to deter human entry and propose preferred methods.

6. Assess the techniques available for emplacing various sealing components and the resulting seal performance that can be expected from each emplacement technique.

7. Assess how different materials can accommodate potential variations in stress, temperature, moisture, and geochemical conditions.

8.3.3.2.4.1.3 Design Subactivity 1.12.4.1.3: Develop advanced conceptual design for seals

Objectives

The objective of this subactivity is to provide design details that can be used to develop the license application design and to support the performance assessment activities.

Description

The advanced conceptual design (ACD) will summarize the results of the trade-off studies performed as part of Subactivity 1.12.4.1.2. The following would be included:

1. The basis for sealing designs.

2. A description of the designs.

3. The design alternatives and a description of how the preferred design is selected.

4. Definition of the uncertainties/design issues associated with the preferred designs.

Some secondary information included as part of the ACD would include preliminary cost estimates for emplacing sealing components (this cost estimate will also include the cost associated with additional research and development that may be required to answer the performance-related questions and finalize designs), a schedule for emplacing sealing components as part of the decommissioning process, and a discussion of activities required to support the performance confirmation program.

8.3.3.2.4.2 Design Activity 1.12.4.2: Development of the license application design for sealing

There are three design subactivities in this design activity.

8.3.3.2.4.2.1 Design Subactivity 1.12.4.2.1: Define subsystem design requirements

Objectives

The objective of this subactivity is to refine design requirements that will assist in the development of sealing components for the license application design (LAD).

Description

The development of design requirements for the LAD is expected to be similar to the categories for Subactivity 1.12.4.1.1. The basis for changes would be the results from Subactivities 1.12.4.1.2 and 1.12.4.1.3, as well as results from ongoing performance assessment activities. Changes are anticipated in the development of performance criteria, design interfaces, and constraints identification.

8.3.3.2.4.2.2 Design Subactivity 1.12.4.2.2: Perform trade-off studies to support license application design development

Objectives

The objective of this subactivity is to provide technical justification for the selection of the final seal designs.

Description

The intent of this task is to perform the remaining trade-off studies that will be necessary to select final seal designs. The remaining design and licensing issue is also expected to be resolved by these studies. Some trade-off analyses would

1. Select the preferred strategies for retaining and dissipating water encountered in the underground facility considering material durability and design adequacy in achieving the desired performance.

2. Define the potential licensing issues and propose a resolution of the issues with consideration of the preferred sealing options.

3. Select the preferred method of backfilling the underground facility and evaluate the most effective way in which to expedite sealing of the drifts.

Although not specifically part of the trade-off studies, a performance assessment of sealing components will be initiated during the advanced conceptual design phase and continue into license application design phase. Results from this assessment will be used to develop and refine the design requirements and performance criteria. The plans for evaluating seal performance are discussed in Section 8.3.5.11.

8.3.3.2.4.2.3 Design Subactivity 1.12.4.2.3: Develop license application design for seals

Objectives

The objective of this subactivity is to provide the license application design for seal components.

Description

The license application design will include the design details primarily for the preferred sealing designs that result from details associated with the tradeoff studies performed as part of Subactivity 1.12.4.2.2 and specific activities performed as part of this task. The following activities would be performed as part of this task.

1. Develop final designs and emplacement procedures for the preferred sealing options.

2. Quantify the physical construction requirements for the emplacement procedures established previously.

3. Develop a reliable cost estimate and a schedule of construction activities needed to emplace the sealing components in the repository. The cost estimates will include a detailed statement of the costs incurred to emplace seal components. Manpower, materials, and equipment requirements will be included.

4. Develop contingency plans for sealing in the event that unforeseen geologic conditions are encountered.

8.3.3.2.4.3 Application of results

The information that is obtained in meeting this information need will contribute directly to the design and performance analysis of the repository seal system. The data will also be used to help satisfy other information needs related to design issues for postclosure repository design (Issue 1.11, Section 8.3.2.2) and preclosure repository design and technical feasibility (Issue 4.4, Section 8.3.2.5). The information will also be used in support of evaluating postclosure performance objectives related to containment, release rates from the engineered barrier system, and total system performance analyses.

8.3.3.2.5 Schedule for seal characteristics (Issue 1.12)

Issue 1.12 (seal characteristics) includes four information needs, which contain one study and four design activities. The schedule information for the study and design activities is summarized in Figure 8.3.3.2-5. This figure includes the study or design activity number and a brief description, as well as major events associated with each. A major event, for purposes of these schedules, may represent the initiation or completion of an activity, completion or submittal of a report to the DOE, an important data feed, or a decision point. Solid lines on the schedule represent activity durations and dashed lines show interfaces among activities as well as data transferred into or out of this design issue. The events shown on the schedule and their planned dates of completion are provided in Table 8.3.3.2-10.

The schedules, in combination with information provided in the logic diagram for this issue (Figure 8.3.3.2-1), are intended to provide the reader with a basic understanding of the relationships between major elements of the site, performance, and design programs. The information provided in Table 8.3.3.2-10 and Figure 8.3.3.2-5, however, should be viewed as a snapshot in time.

The overall program schedule presented here is consistent with the Draft Mission Plan Amendment (DOE, 1988a). The site characterization program will undergo a series of refinements following issuance of the statutory SCP. Refinements will consider factors both internal and external to the site characterization program, such as changes to the quality assurance program. Such refinements are to be considered in ongoing planning efforts, and changes that are implemented will be reflected in the semiannual progress reports. Summary schedule information for this and other repository design issues can be found in Sections 8.5.3 and 8.5.6.

Table 8.3.3.2-10. Major events and planned completion dates for studies and design activities in Issue 1.12 (seal performance) (page 1 of 3)

Study/design activity number	Brief description of study/design activity	Major event[a]	Event description	Date
1.12.1	Compile information for seal design	A	Complete compilation of preliminary list of information needed for seal design for advanced conceptual design (ACD); continue to compile information needed for seal design	9/89
		B	Complete compilation of updated list of information needed for seal design for license application design (LAD)	7/91
		C	Complete compilation of information used for seal design for license application (LA)	1/94
1.12.2.1 (ongoing)	Seal material properties development	A	Continue determination of testing requirements	10/88
		B	Study plan approved	9/89
		C	Begin Phase I testing of seal material properties	3/90
		D	Begin Phase II testing of seal material properties	6/90
		E	Begin crushed tuff properties tests	7/90
		F	Complete Phase I material testing	3/91
		G	Complete Phase II testing of seal material properties	6/91
		H	Draft report available to the U.S. Department of Energy (DOE) on the results of Phase I testing	1/92

Table 8.3.3.2-10. Major events and planned completion dates for studies and design activities in Issue 1.12 (seal performance) (page 2 of 3)

Study/design activity number	Brief description of study/design activity	Major event[a]	Event description	Date
1.12.2.1 (ongoing)	Seal material properties development (continued)	I	Draft report available to the DOE on the results of Phase II testing of seal material properties	6/92
		J	Draft report available to the DOE on results of the crushed tuff properties test	6/92
		K	Preliminary long-term test data available for last input to seal subsystem performance assessment; long-term testing of seal components continues as performance confirmation	5/93
1.12.2.2 (ongoing)	Development of degradation model for cementitious materials emplaced in a tuffaceous environment	A	Complete preliminary degradation model for cementitious sealing materials	10/88
		B	Complete updates to degradation models for cementitious sealing materials	8/91
1.12.4.1 (ongoing)	Development of ACD for sealing	A	Input from degradation model for update of sealing design requirements for start of ACD	10/88
		B	Complete update of sealing design requirements for ACD	8/89
		C	Recommend final sealing materials for license application design to the DOE	9/91
		D	Complete ACD for sealing	1/92

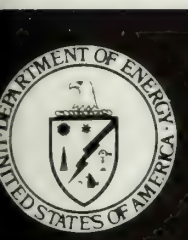
Table 8.3.3.2-10. Major events and planned completion dates for studies and design activities in Issue 1.12 (seal performance) (page 3 of 3)

Study/design activity number	Brief description of study/design activity	Major event[a]	Event description	Date
1.12.4.2	Development of LAD for sealing	A	Begin seal subsystem performance assessment; begin developing sealing criteria for start of LAD	8/89
		B	Complete seal design report for LAD	9/91
		C	Begin evaluation of reasonably available technology for sealing components	1/92
		D	Information on testing of seal materials available for seal subsystem performance assessment	5/92
		E	Last input on the results of seal material properties testing for completion of seal subsystem performance assessment	6/93
1.12.4.2	Development of LAD for sealing (continued)	F	Draft report available to the DOE on seal subsystem performance assessment	1/94
		G	Incorporate results of the evaluation of reasonably available technology of sealing components into the LAD report	8/94

[a]The letters in this column key major events shown in Figure 8.3.3.2-5.

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)



Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.4, Waste Package Program

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.4 WASTE PACKAGE PROGRAM

The waste package program is organized to address two performance issues (Issues 1.4 and 1.5) and three design issues (Issues 1.10, 2.6 and 4.3) included in the issues hierarchy. This section describes the overall waste package postclosure compliance strategy and the design issues of the waste package program for the Yucca Mountain Project (formerly called the Nevada Nuclear Waste Storage Investigations Project). The performance issues of the waste package program are discussed in Sections 8.3.5.9 and 8.3.5.10.

Section 8.3.4.1 provides an overview of the program. The design activities and site data needs for addressing the postclosure waste package requirements are described in Section 8.3.4.2 (Issue 1.10). This discussion includes a description of the studies and activities required to characterize the waste package emplacement environment. Section 8.3.4.3 describes the preclosure containment requirements for the waste package and discusses the information to be obtained on waste forms (Issue 2.6). Information needed to develop the technologies for production of the waste package is described in Section 8.3.4.4 (Issue 4.3).

Sections 8.3.5.9 and 8.3.5.10 discuss the waste form, package materials, and site data needs and describe the activities planned to demonstrate compliance with the performance objectives for waste package containment and engineered barrier system release.

The schedule information provided in this section includes the sequencing, interrelationships, and durations of the design activities and should be regarded as a snapshot in time. Section 8.5 presents the major milestones, decision points, and summary schedule information for the repository program.

Waste package postclosure compliance strategy

The waste package postclosure compliance strategy is designed to resolve waste package issues in an integrated manner as shown in Figure 8.3.4-1. The waste package issues and information needs are based on the requirements in the U.S. Nuclear Regulatory Commission's (NRC) 10 CFR Part 60 with considerations of the Nuclear Waste Policy Act of 1982, the U.S. Environmental Protection Agency's 40 CFR Part 191, the U.S. Department of Energy's (DOE) 10 CFR Part 960, and the Generic Requirements for the Mined Geologic Disposal System (MGDS). Figure 8.3.4-1 provides an overview of the process that the Yucca Mountain Project is following to develop a licensable, cost-effective waste package design on the required schedule. This simplified format depicts only the key elements of the waste package program strategy and the major interactions among them. For the purposes of the site characterization plan, the Yucca Mountain Project has adopted the DOE interpretations for the regulatory terms "substantially complete containment," "engineered barrier system," and "anticipated processes and events."

Approaches taken by the Project for the waste package postclosure compliance strategy are to employ multiple barriers consistent with the NRC's philosophy and to use logical and defensible arguments based on scientific investigations and engineering analyses. From the existing data bases for waste forms, characteristics of the Yucca Mountain site, and the preliminary

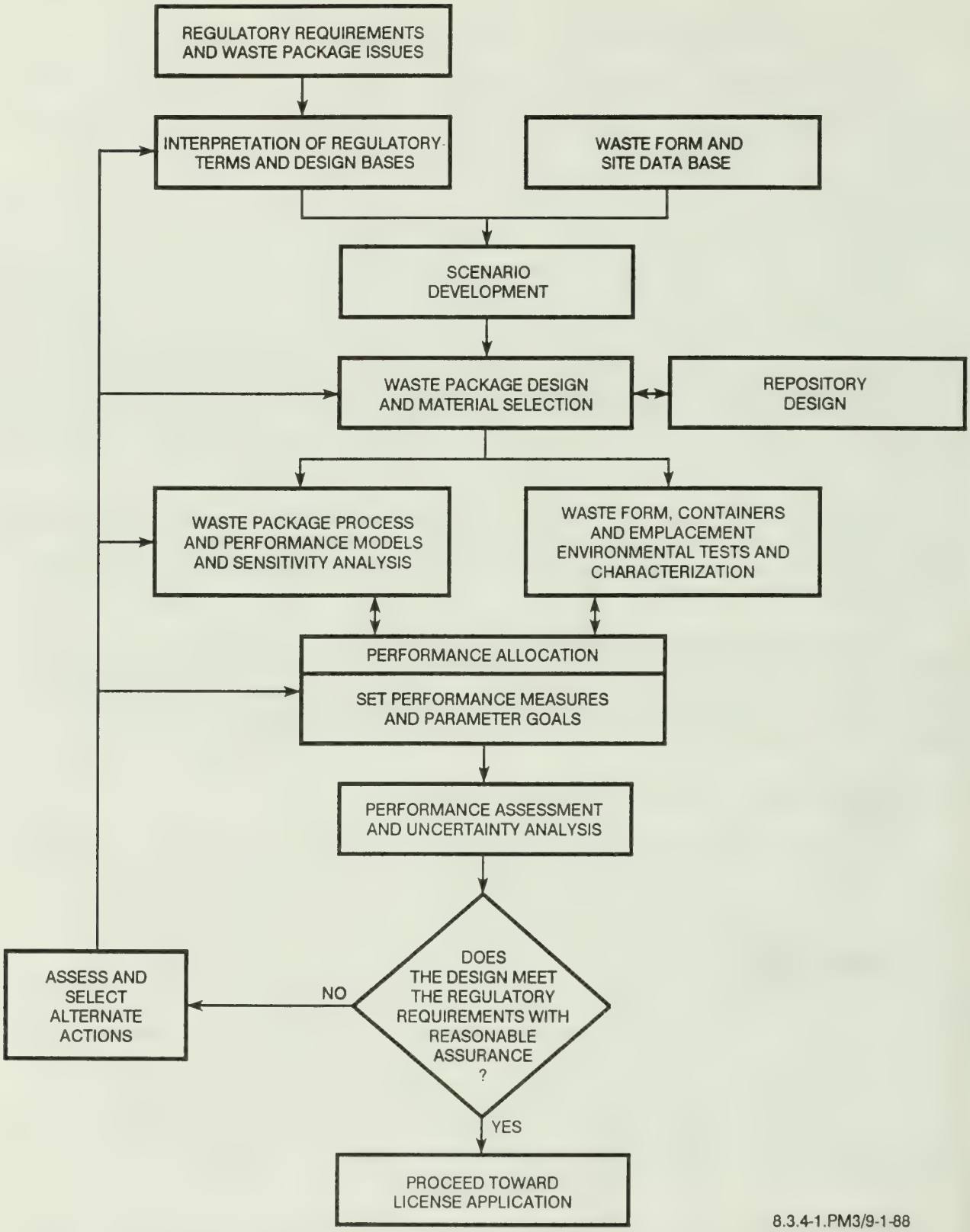


Figure 8.3.4-1. Waste package postclosure compliance strategy

process and event scenarios, the Project has developed a waste package concept and a coupled waste package near-field environment scenario, from which a conceptual waste package design has evolved. The conceptual design in turn provides the basis for the development of the waste package testing and performance assessment activities utilizing computational models. These models are used to guide the design and testing programs and to aid in performance allocation to waste package components. Sensitivity analyses are performed to quantitatively relate performance measures (e.g., containers breached versus time) to design or environment parameters.

The essence of the waste package compliance strategy lies in the iterative process of performance allocation, performance assessment, testing to determine if goals are met, and, if not, evaluation and selection of alternative actions such as changes in waste package design or materials, modification of computational models, performance of additional tests to improve data bases for the waste package and the environment, or the reallocation of component performance. It is also possible that an alternative definition or interpretation of the regulatory terms "substantially complete containment" and the "engineered barrier system" by the NRC or the DOE may change the performance allocation. The iterative process continues until the performance objectives are met with reasonable assurance. The selection of the alternative actions will be determined based on the results of performance assessment.

The waste package postclosure compliance strategy for the Yucca Mountain Project is structured within an issues hierarchy, and the performance allocation process is used to resolve the issues. There are three interrelated issues on postclosure performance of the waste packages. Sections 8.3.4.2, 8.3.5.9, and 8.3.5.10 discuss the specific performance allocation strategies to resolve the Issues 1.10, 1.4, and 1.5, respectively. The Yucca Mountain Project has chosen to allocate performance to the components of the waste package, namely the container and the waste form, together with the near-field environment as altered through engineering design.

The waste package design strategy takes advantage of the unsaturated nature of the Yucca Mountain site. The near-field environment will also be engineered by designing the waste package emplacement configuration and thermal loading to enhance the unsaturated condition and inhibit liquid water contacting the waste packages during the containment period. For the bounding condition, the Project assumes that water will contact some of the packages, and hence containment performance has been allocated to the package components. However, the expected quality of the water is such that it will have little impact on the long-term integrity of the waste packages.

Substantially complete containment, as interpreted by the DOE in this section, relies on the container and waste form. The Yucca Mountain Project has selected six metallic corrosion-resistant container materials as candidates for further evaluation. These materials fall generally into two alloy families selected to avoid common mode failure due to localized corrosion modes. The material selection criteria, which will be peer-reviewed, include the material properties, fabricability and closure requirements, and the ability to model the performance of the container over

time under anticipated repository conditions to predict with confidence that the containment and release rate goals can be met. As a backup to metallic containers, alternative container materials and designs are also being evaluated. Performance is also allocated to the glass and spent fuel waste forms. For spent fuel, reliance is placed on the cladding during the early years to limit the release of the radionuclides with short half lives. Reliance is also placed on the fuel matrix to limit the release of actinides and other radionuclides.

During the post-containment period, primary reliance is placed on the properties of the waste form to achieve the goal of limiting the release of radionuclides from the engineered barrier system. Performance is also allocated to other components.

Performance is allocated to the engineered environment for both periods. The expected condition is that the site will remain unsaturated for both the containment and post-containment periods. Use of the engineered near-field environment and the nature of the unsaturated site (i.e., high matric potential) will play an important role in limiting accessibility of liquid water to the waste packages.

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.4.1, Waste Package Overview

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.4.1 Overview

Section 8.3.4 describes the plans for completing the waste package design tasks through the sequence of design phases leading to the preparation of a license application. The tasks are organized to address three design issues included in the issues hierarchy. (See Section 8.2 for a listing of the issues and a description of the general approach to resolving these issues.) These three issues are

1.10 Characteristics and configurations of the waste packages, including the package environment (postclosure)

2.6 Characteristics and configurations of the waste packages (preclosure)

4.3 Waste package production technologies

These issues are discussed in Sections 8.3.4.2 (Issue 1.10), 8.3.4.3 (Issue 2.6), and 8.3.4.4 (Issue 4.3).

The tasks to be undertaken for these three issues are closely related to issues discussed in several other sections of this document. Requirements and constraints are imposed on the waste package designs by the postclosure regulatory performance objectives for the engineered barrier system. The performance issues that address these objectives are discussed in Section 8.3.5. These performance issues also provide the properties of the waste forms and container materials that are needed to design the packages. The waste package designs are closely coupled to the repository designs because one of the important missions of the repository is the assembly and emplacement of the waste packages. The detailed discussions of the repository design issues are in Section 8.3.2.

In one important respect, the division of the waste package design issues into preclosure and postclosure categories is somewhat artificial. Although the requirements and constraints on the package designs differ for the two time frames, there will be only one set of package designs. After emplacement, the environment that the packages will experience does not strongly depend on whether the repository is operational or closed. To avoid unnecessary duplication and to improve continuity of the discussions, the material discussed under the preclosure issues is primarily related to the production, handling, and emplacement of the packages. The postemplacement aspects of the package designs are discussed under the postclosure issue. The relationship between the package design issues, and their relationships to the repository design, and the directly relevant performance issues is shown in Figure 8.3.4.1-1.

As indicated in the figure, the waste package postclosure design issue (1.10) is linked directly to the two performance issues (Issues 1.4 and 1.5, discussed in Sections 8.3.5.9 and 8.3.5.10, respectively) related to the ability of the waste package and engineered barrier system to meet the performance objectives of 10 CFR 60.113. The reason for this relationship is twofold: (1) some of the information needed to perform the package design is developed in the activities described under the performance issues (1.4 and 1.5) and (2) the performance issues require information developed under the

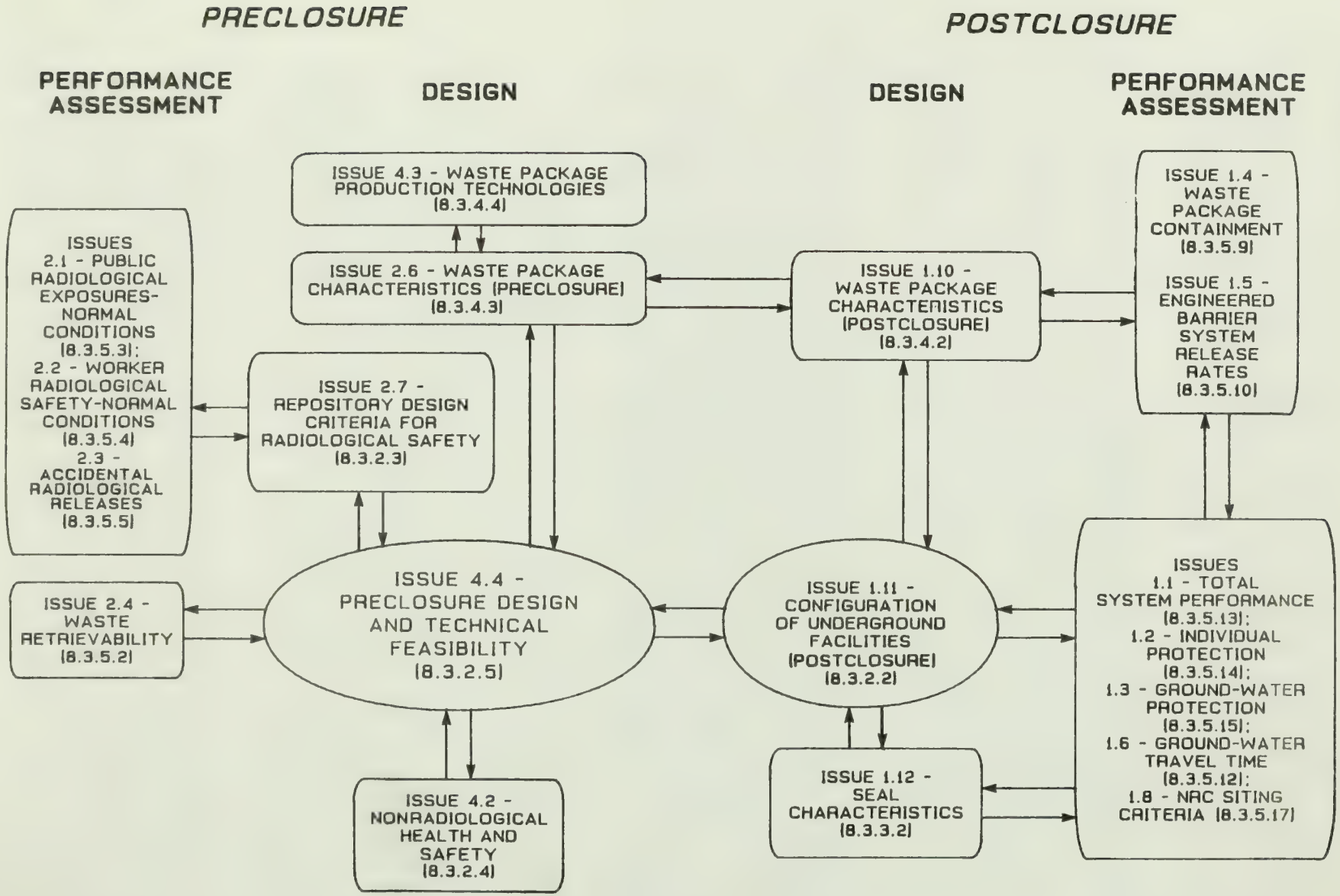


Figure 8.3.4.1-1. Relationships between design- and performance-related issues used directly in performance allocation.

design issue for their resolution. Specific examples of the information that must be exchanged between these issues include container material properties (from Issue 1.4, Section 8.3.5.9), waste form characteristics and configurations (from Issue 1.5, Section 8.3.5.10), and the postclosure environment of the waste packages and the package design configurations (from Issue 1.10, Section 8.3.4.2).

The required postclosure performance of the waste packages, together with the waste form and container material properties, presents a set of design criteria and constraints on the preclosure aspects of the package design. These criteria, and the feedback to the postclosure issues, are also depicted in Figure 8.3.4.1-1. The postclosure performance-derived criteria, together with the preclosure criteria, establish the design requirements to be translated into the package design in Issue 2.6 (Section 8.3.4.3) and reflected in the development of package production technologies in Issue 4.3 (Section 8.3.4.4).

The interaction of the waste package design issues with the repository design issues (both preclosure and postclosure) is handled by the transfer of design criteria and design evaluations between respective issues. Thus, Issues 2.6 and 4.3 will generate criteria for the design of those portions of the repository facilities, equipment, and operations that concern waste packaging, handling, and emplacement to be implemented in Issue 4.4 (Section 8.3.2.5). Similarly, design criteria for the postclosure repository configuration that will influence the waste packages will be generated in Issue 1.10 (Section 8.3.4.2) and implemented in Issue 1.11 (Section 8.3.2.2).

By establishing the relationships just described, a logical mechanism for integrating the waste package and repository subsystems is defined in a way that permits the necessary transfer of design information with minimum duplication; it also provides for adequate feedback between the subsystem designs to verify consistency. The designs are linked to the appropriate performance issues so that the assessments required to demonstrate compliance with the regulations can be made with confidence.

Of the three waste package design issues discussed in this section, only one directly involves the acquisition of site characterization data. Issue 1.10 requires the development of sufficient data, both from the site and in the laboratory, to define the ranges of the anticipated near-field environment conditions, resulting from all anticipated processes and events, for which the emplaced waste packages will be designed. These data will be developed in the activities described in Section 8.3.4.2 and by reference to the relevant site investigations described in Section 8.3.1 (site program). The lack of in situ data on this environment represents a major uncertainty in the adequacy of the design concepts that have been developed in the past (Chapter 7). These data are vital to the successful completion of the waste package designs and the assessments of their performance. To provide resolution of this issue, the results of the waste package and repository design activities also are needed. This reference design information is transferred to the performance issues (1.4 and 1.5) to be used, in conjunction with the other information developed within those issues, in assessments of the engineered barrier system performance.

The other two issues addressed in this section, Issues 2.6 (Section 8.3.4.3) and 4.3 (Section 8.3.4.4), do not directly involve the acquisition of site characterization data. The package designs that evolve under Issue 2.6 must comply with the regulatory design criteria and restrictions on their contents and must be compatible with the repository operations, including maintaining the capability for waste retrieval. The performance-derived criteria and environmental design envelope as received from Issue 1.10 (Section 8.3.4.2) must be accommodated in the designs. Issue 4.3 (Section 8.3.4.4) is restricted to the establishment of technologies capable of producing the packages as designed with a high degree of reliability. These technologies do not require site data since the designs will reflect the requirements imposed by the site characteristics.

8.3.4.1.1 Waste package environment

The environment into which the waste package will be placed and the effect of the waste package on that environment are central elements of waste package design and performance analysis. Our present understanding of the environment at the repository level at Yucca Mountain is summarized in Section 7.1 and in the following paragraphs of this overview. The anticipated range of near-field environmental conditions considers the effects of the range of anticipated processes and events. The work that has been done to characterize alteration to the environment caused by emplacement of waste packages is described in Section 7.4.1.

The repository would be sited above the water table at Yucca Mountain. The emplacement holes are expected to remain free of standing water for the anticipated range of vadose water percolation rates through the repository level and expected permeability of the host rock. The rock characteristics indicate that the boreholes would remain open except for some sloughing of rock from the borehole wall. This implies that the waste packages will not be subjected to large pressures or stresses from rockfall. The pores in the rock at the repository level are filled with a mixture of air and water. This situation will result in oxidizing conditions in the vicinity of the waste package. The repository rock is expected to contain fractures spaced at intervals that are sufficiently close to produce at least one fracture intersection with each emplacement borehole. Site characterization will allow determination of the range of anticipated conditions.

The vadose water is expected to have a chemical composition of dissolved solids similar to that found in well J-13. The J-13 water is predominantly a dilute solution of sodium bicarbonate with moderate amounts of silica, calcium, and sulfate and small amounts of potassium, nitrate, chloride, and fluoride. This water has been used as the reference water for waste package testing. When water is available from the repository horizon, its composition will be compared with that from well J-13. A program of confirmatory testing will then be developed, based on the level of similarity of the vadose water to that of well J-13, to relate the testing using well J-13 water and the testing based on the vadose water composition.

The repository construction will cause changes in the characteristics of the emplacement environment. These changes could have a substantial impact

on the subsequent performance of the waste package. As part of the performance allocation process, goals were established for the level of change that could be tolerated without resulting in an altered situation that would invalidate the waste package components testing program. These goals are discussed in Section 8.3.4.2.

Unanticipated but credible processes and events are included in the evaluation of Issue 1.1, total system performance (Section 8.3.5.13). The waste package environments due to interaction of the waste packages with such unanticipated processes and events will be determined to the extent needed to evaluate the radionuclide source term for use in the resolution of Issue 1.1.

8.3.4.1.2 Waste package components

The reference designs for Yucca Mountain Project waste packages consist of various components that depend on the waste form. For spent-fuel waste packages, the components are the spent fuel (in the form of intact assemblies, boxed consolidated rods, or rods consolidated at the repository) and the container into which the spent fuel would be placed. Spent fuel is considered to consist of the uranium dioxide fuel encased in the cladding in which the fuel saw service in the reactor, together with any associated assembly structural materials. Reprocessed waste from the Defense Waste Processing Facility or the West Valley Demonstration Project will come to the repository as a borosilicate glass waste form inside a stainless steel pour canister. The canister will be placed into a metal container similar to that to be used for spent fuel.

To address the possibility that the range of anticipated processes and events will include waste package environment conditions that are more aggressive than can be tolerated by the reference metal container designs, alternative container concepts will be evaluated. These alternatives may include additional components, such as ceramic liners, metallic or other fillers, or coatings, that will significantly alter the modes of container degradation and radionuclide release. Additional descriptions of the activities associated with evaluation of these alternative concepts are included in the activities supporting the resolution of Issue 1.4 (Section 8.3.5.9). These alternatives may also provide additional control of the release of gaseous nuclides, such as carbon-14, from spent fuel that may be released upon container breach.

8.3.4.1.3 Waste package designs

Waste package designs must provide for preclosure and postclosure performance objectives. The criteria for design are based on requirements discussed in Section 7.2.1. The waste package will be designed to provide containment under normal loads imposed by the handling and emplacement systems and will assist in containment under accident conditions. One design approach for the waste package is to obtain information relative to the loads imposed by the handling and emplacement systems and to design the waste package for those load configurations. A second approach is to design the waste

package to meet the overall performance objectives and then to design the handling systems around the waste package strength criteria that resulted. The latter approach has been taken for the conceptual design discussed in Section 7.3. However, the waste package must be designed to consider the overall repository system, including considerations of identification, handling or lifting fixtures, and imposed loads. Thus, the waste package design may be modified in the advanced conceptual design report to reflect the overall repository system. Such modifications are not expected to affect the issue resolution strategy or the information needs.

The preclosure control of criticality and limitation of reactive materials and free liquids are independent of site characterization and will be provided for in the design of the operating system and the waste package. Under normal conditions, preclosure release control will be provided by the waste package container and is thus independent of site characteristics. During accident conditions, the waste package will contribute to the overall system, but again the performance is independent of site characteristics. Preclosure (but postemplacement) temperature limitation is not a function of the waste package alone but includes the emplacement configuration and rock thermal properties. The control of preclosure emplacement temperature will require information regarding thermal properties of the rock and is discussed in Section 8.3.2.2. The final requirement, that the design provide for the use of reasonably available technologies to fabricate, assemble, close, and inspect the waste package, is discussed in Section 8.3.4.4. The information needed to design the waste package for preclosure performance objectives is discussed in Section 8.3.4.3.

The postclosure performance objectives require that the waste package design consider site characteristics. Radionuclide containment will be provided during the 300 to 1,000 yr after closure by the waste package container and the properties of the waste forms. Therefore, the container must be designed to provide substantially complete containment in the emplacement environment. The materials, fabrication techniques, and material thicknesses will be specified after consideration of the site characteristics discussed in Sections 7.1 and 7.4.1, with additional information needed discussed in Section 8.3.4.2. After the containment period, the performance objective is based on the controlled release rate from the engineered barrier system as specified in 10 CFR 60.113(a)(1)(ii)(B). Demonstration that this objective is met is also based on container and waste form performance. There is no discussion of the waste form design in this section. The focus of Yucca Mountain Project effort is to characterize the release rates of radionuclides from the waste forms under the postemplacement site environmental conditions. The performance allocation and issue resolution strategy related to the postclosure performance assessment are discussed in Sections 8.3.5.9 and 8.3.5.10.

8.3.4.1.4 Waste package modeling

Waste package modeling will be required to support both design and performance information needs. Modeling will be performed to address both preclosure and postclosure information needs. Modeling efforts supporting design include stress analysis for preclosure handling, emplacement and retrieval scenarios, and analysis of stress caused by emplacement borehole failure. Further, design calculations are required for thermal analysis to determine temperatures of waste package components as a function of waste form characteristics.

Postclosure modeling is required to support performance assessment calculations. Much of this activity is included in the waste package performance assessment effort discussed in greater detail in Sections 7.4.5 and 8.3.5.10. Models of the processes that affect loss of containment and radionuclide release will be integrated into the performance assessment calculation models. These models will include the processes of waste form degradation and radionuclide release, barrier degradation, geochemical changes and transport of materials in the waste package environment, and transport analysis within the breached containers.

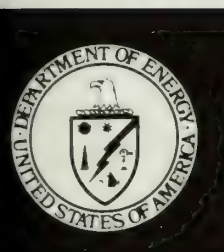
Many of these modeling activities will synthesize empirical data into mathematical constructs to represent processes that occur following waste package emplacement. The corrosion and waste form degradation and release models are likely to be of this form. Models of other processes mentioned previously will be formulated from the governing differential equations and constitutive relationships. Thermal and mechanical analyses, geochemical equilibrium and kinetics calculations, and hydrothermal flow and transport simulations are expected to be of this form.

The modeling activities will be conducted at two levels. The first level will be a rigorous attempt to simulate processes in two or three dimensions to identify the most sensitive model parameters and obtain a fundamental understanding of the processes. After these modeling activities are complete, a second level of modeling will be used to derive simpler models that are appropriate for use in performance assessment calculations.

Both levels of modeling must demonstrate that the processes are adequately represented for the required waste package performance predictions. Therefore, substantial effort will be required to evaluate these models. The plans to acquire information from the site characterization program to test these models are discussed in Section 8.3.5.20.

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)



Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.4.2, Waste Package Characteristics (Postclosure)

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.4.2 Issue resolution strategy for Issue 1.10: Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.135 and (b) provide information to support resolution of the performance issues?

Regulatory basis for the issue

This issue deals with two aspects of the waste package postclosure behavior. The first aspect relates to the specific requirements contained in Section 135(a) of the NRC rule that states, in part:

(1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

These requirements will be addressed by gathering the information detailed under Information Needs 1.10.1 (Section 8.3.4.2.1) and 1.10.4 (Section 8.3.4.2.4).

The second part of this issue is more global in its application. Many of the performance issues require information on the behavior of the waste package. To provide this information, appropriate testing and analyses of the waste package components and system must be done. To identify appropriate tests and analyses, the service environment for the waste package must be determined.

The waste package environment, upon initial emplacement of the package, will depend on the ambient conditions at the repository level and how those conditions are altered by repository construction and operation. The environment following emplacement will depend on the initial emplacement conditions and how those conditions are altered by the waste package characteristics. Therefore, there is an interactive process between design and environment characterization. The design is initially based on the ambient conditions and a prediction of how those conditions would alter under the stresses applied by repository construction and waste emplacement. Once a design is available, analysis of that design provides a set of environmental stress factors. Testing is then done to determine the effects of those stresses, such as thermal and radiation fields and mechanical stresses, on the package environment. Based on those tests and subsequent analyses, designs may be modified and the test and analysis cycle repeated. The relationships among design, environmental, and performance considerations are presented in Figure 8.3.4.2-1.

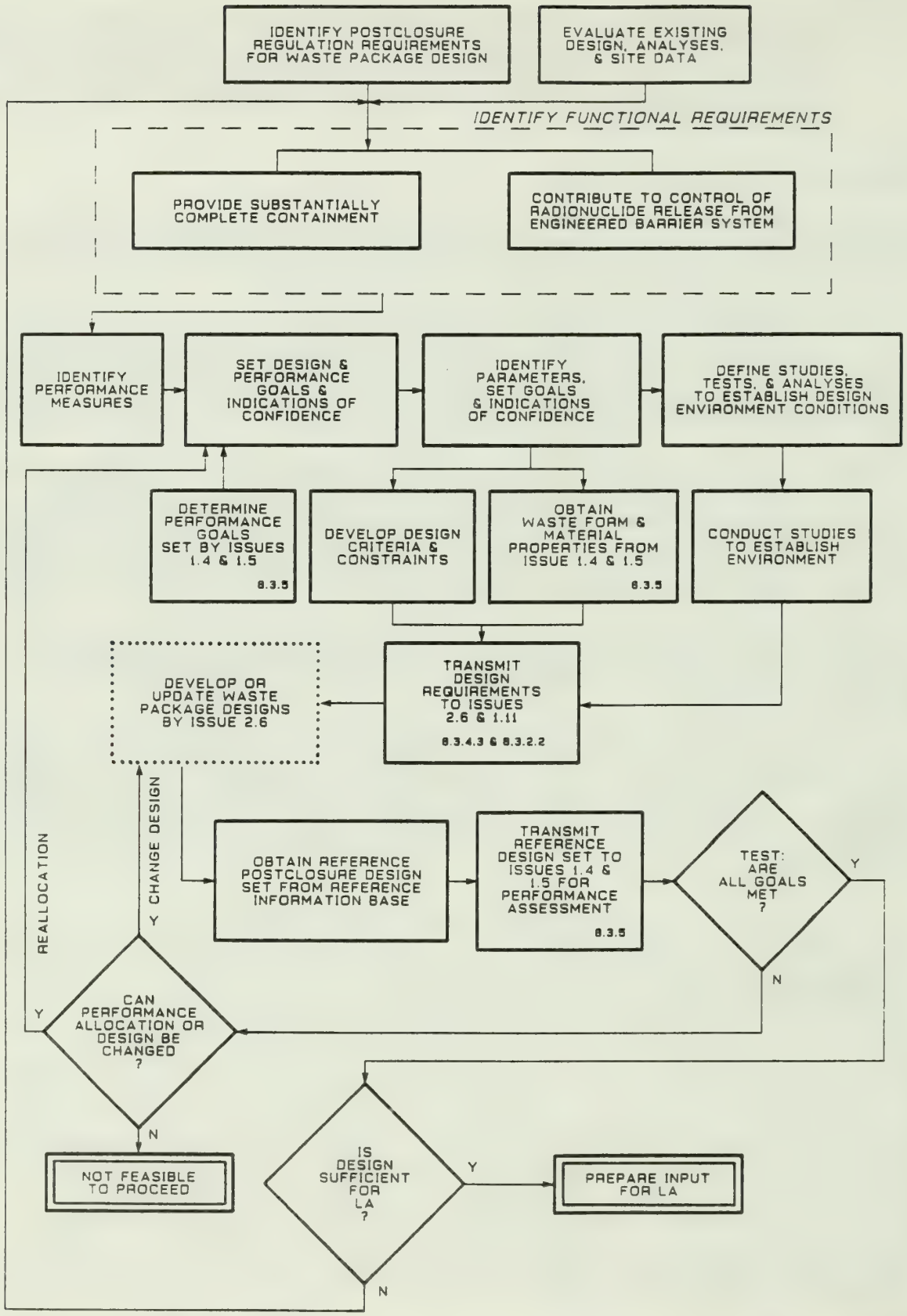
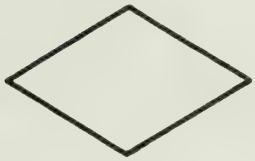


Figure 8.3.4.2-1a. Logic diagram for the resolution of Issue 1.10 (postclosure waste package characteristics). See Figure 8.3.4.2-1b for legend.

LEGEND



ACTIVITY PERFORMED TO RESOLVE ISSUE



TEST TO DETERMINE SUBSEQUENT ACTIVITY



ACTIVITY PERFORMED BY INDICATED ISSUE



ACTIVITY WITH MULTIPLE SIMILAR ACTIVITIES OR TESTS



DECISION ABOUT ISSUE RESOLUTION

Y - YES N - NO LA - LICENSE APPLICATION

Figure 8.3.4.2-1b. Legend for Figure 8.3.4.2-1a

The information gathered to resolve this issue will provide the waste package design information and environment description to be used in the performance issues that will describe engineered barrier system compliance with the regulations contained in 10 CFR 60.113. The design and environment description, together with the performance predictions developed under Issues 1.4 and 1.5 (Sections 8.3.5.9 and 8.3.5.10), will provide input data on the source term for radionuclide release, which are necessary to resolve other issues. Source term data will be used in Issues 1.1 (Section 8.3.5.13), 1.8 (Section 8.3.5.17), and 1.9 (Section 8.3.5.18). Issue 1.1 includes evaluation of unanticipated but credible processes and events. Although not included in the basis for design of the waste packages and evaluation of performance Issues 1.4 and 1.5, the near-field environments due to the interaction of waste packages with unanticipated processes and events will be evaluated to the extent necessary to provide input to Issue 1.1.

Approach to resolving the issue

There are many factors to be considered in the development of waste package designs and the analysis of the effect of those designs on the environment. To resolve this issue, a high degree of interaction between design, site characterization, and waste package component performance analyses is necessary.

Identified by highlighting in Figure 8.3.4.2-2 are the products, models, and submodels that provide input to resolution of Issue 1.10. Issue resolution is accomplished by producing a description of waste package/near-field interactions (Information Need 1.10.1) that addresses the factors identified in 10 CFR 60.135 and incorporating these interactions into waste package design considerations. In Table 8.3.4.2-1 the specific activities that provide data for model development are in the SCP sections indicated, along with the model hierarchy. The models and submodels also provide information necessary for resolution of Issues 1.4 and 1.5 through the input pathways indicated in Figure 8.3.4.2-2. In addition, development of the source term (Information Need 1.5.5) requires as input the near-field flow and transport model developed from the description of the postemplacement, near-field environment (Information Need 1.10.4). The testing and design activities described in this section are tentative and are subject to change. Any such change will be reported in semiannual progress reports.

To develop a description of the postemplacement, near-field environment and satisfy Information Need 1.10.4, it is necessary to identify anticipated physical interactions between the as-assembled waste package and the environment that may affect waste container integrity. These physical interactions will be expressed as performance measures that represent design goals for rock-induced load on the waste package, waste package thermal environment, tectonic processes, materials selection, and container handling. These performance measures and their tentative goals are given in Table 8.3.4.2-2. The performance parameters, their respective performance measures, their respective tentative goals, and the expected parameter values are given in Table 8.3.4.2-3. The activities that address these goals are described in Section 8.3.4.2.4.

To satisfy Information Need 1.10.4, it is also necessary to obtain input from studies that characterize the postemplacement mineralogy and water

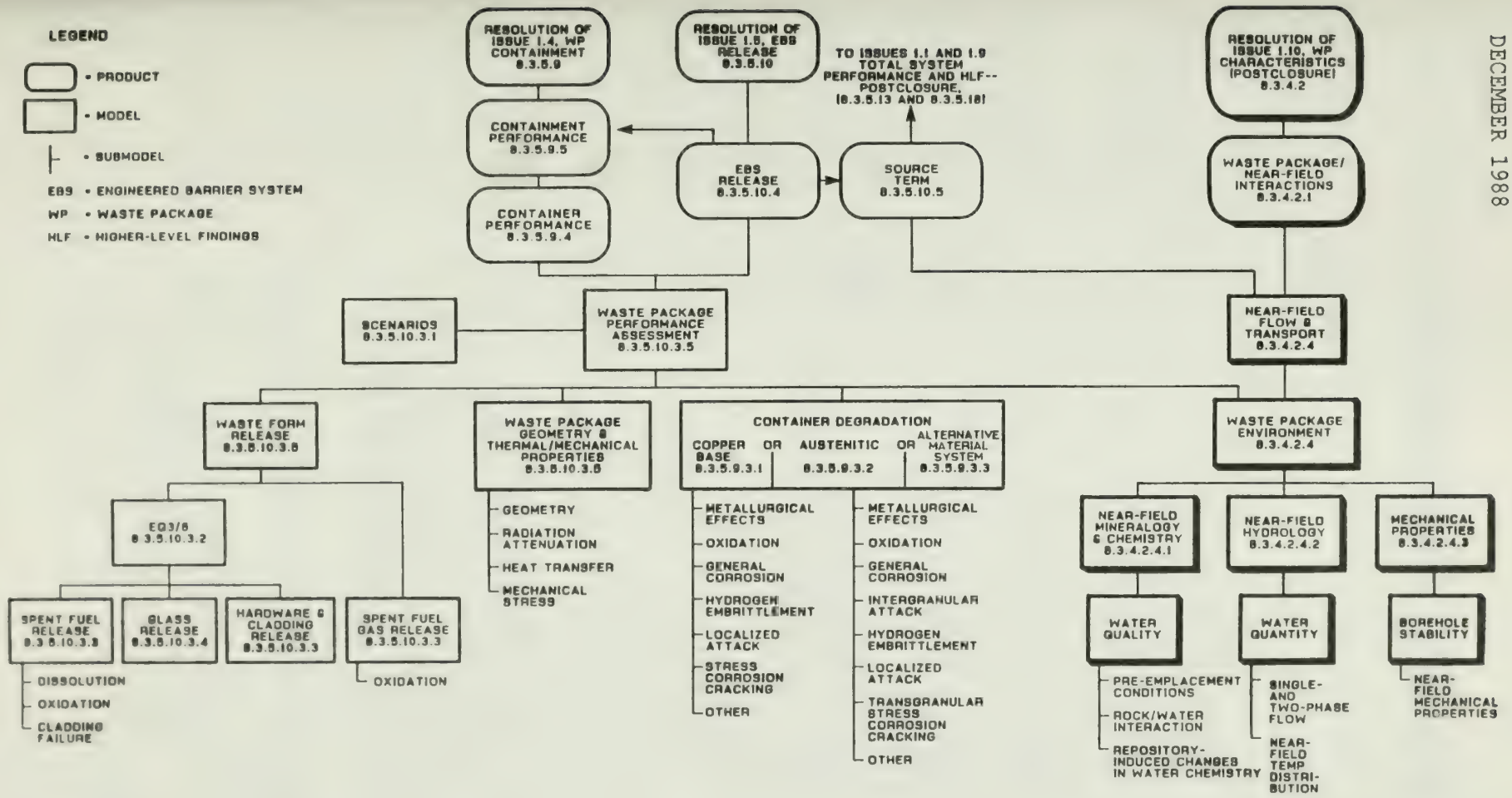


Figure 8.3.4.2-2. Model hierarchy for Issue 1.10 (waste package characteristics—postclosure).

Table 8.3.4.2-1. Model hierarchy and model inputs for Issue 1.10 (waste package characteristics--postclosure)

Model	Model input	Needed confidence	SCP section[a]
Near-field flow and transport	For Topopah Spring Tuff at repository horizon (TSw2)[b]:		
	Hydraulic conductivity of matrix for liquid phase	High	8.3.1.2.2
	Porosity of matrix	High	8.3.1.2.2
	Water retention curves	High	8.3.1.2.2
	Relative permeability curves	High	8.3.1.2.2, 8.3.4.2.4
	Knudsen diffusion coefficients	Medium	8.3.1.2.2
	Fracture permeabilities	High	8.3.1.2.2
	Fracture orientation	Medium	8.3.1.2.2
	Fracture porosity	High	8.3.1.2.2
	Fracture spacing	Medium	8.3.1.2.2
	Heat output of packages	High	8.3.4.2.2
	Thermal conductivity of matrix	High	8.3.1.15.1
	Heat capacity of matrix	High	8.3.1.15.1
	Bulk density of matrix	High	8.3.1.15.1
	Radionuclide releases from container	High	8.3.5.10.4
	Effective sorption coefficients for radionuclides released from package	High	8.3.1.3.4
	Effective solubilities of radionuclides in vadose pore water	Medium	8.3.1.3.5
	Diffusion coefficients for radionuclides in rock matrix	High	8.3.1.3.6
	Dispersivity for radionuclides in rock matrix	Medium	8.3.1.3.6
	Distribution of recharge rates through repository horizon in time and space	High	8.3.1.2.2
Waste package environment	Mineralogy and chemistry of pre- and postemplacement environment	High	8.3.4.2.4.1
	Near-field hydrology	High	8.3.4.2.4.2
	Thermal and mechanical properties of the postemplacement waste package environment	High	8.3.4.2.4.3

Table 8.3.4.2-1. Model hierarchy and model inputs for Issue 1.10 (waste package characteristics--postclosure) (continued)

Model	Model input	Needed confidence	SCP section[a]
Mineralogy and chemistry	Mineralogy and water quality		
	Rock-water interaction at elevated temperature	High	8.3.4.2.4.1.1
	Repository material-induced changes in water chemistry	High	8.3.4.2.4.1.2
	Vadose water composition	High	8.3.4.2.4.1.3
	Dissolution-precipitation effects on water chemistry	Medium	8.3.4.2.4.1.4
	Radiation-induced changes in water chemistry	High	8.3.4.2.4.1.5
	Corrosion-induced changes in water chemistry	Medium	8.3.4.2.4.1.6
Near-field hydrology	Water quantity	High	8.3.4.2.4.2
	Single-phase fluid flow	High	8.3.4.2.4.2.1
	Two-phase fluid flow	High	8.3.4.2.4.2.2
Thermal and mechanical properties	Thermal loading	High	8.3.4.2.4.3
	Near-field temperature distribution	High	8.3.4.2.4.3.1
	Borehole stability	High	8.3.4.2.4.3
	Near-field mechanical properties	High	8.3.4.2.4.3.2
Borehole stability	Fracture orientation and density		
	Average spacing within each borehole	High	8.3.4.2.4.3.2
	Set identification	High	8.3.4.2.4.3.2
	Distribution of orientation	High	8.3.4.2.4.3.2
	Average dip of set	High	8.3.4.2.4.3.2
	Average azimuth of set	High	8.3.4.2.4.3.2
	Fracture stiffness		
	Aperture	Medium	8.3.4.2.4.3.2
	Normal stress	High	8.3.4.2.4.3.2
	Shear stress	High	8.3.4.2.4.3.2
	Joint roughness coefficient	Medium	8.3.4.2.4.3.2
	Fracture shear strength		
	Joint roughness coefficient	High	8.3.4.2.4.3.2
	Joint compressive strength	Medium	8.3.4.2.4.3.2
	Residual friction angle	High	8.3.4.2.4.3.2

Table 8.3.4.2-1. Model hierarchy and model inputs for Issue 1.10 (waste package characteristics--postclosure) (continued)

Model	Model input	Needed confidence	SCP section[a]
Borehole stability (continued)	Emplacement geometry		
	Hole orientation	High	8.3.4.2.4.3.2
	Hole dimensions	Medium	8.3.4.2.4.3.2
	Thermal properties of rock		
	Coefficient of linear expansion	Medium	8.3.4.2.4.3.2
	Rock temperature	Medium	8.3.4.2.4.3.2
	Mechanical and thermal stress loading		
	Poisson's ratio	Medium	8.3.4.2.4.3.2
	Unit weight	Medium	8.3.4.2.4.3.2
	Principal stress magnitude	Medium	8.3.4.2.4.3.2
	Joint roughness	High	8.3.4.2.4.3.2
	Principal stress orientations	Medium	8.3.4.2.4.3.2
	Mineral alteration		
	Coefficient of thermal expansion	Medium	8.3.4.2.4.3.2
	Modal abundance of water-rock interaction products	Medium	8.3.4.2.4.1.1

[a]The SCP section references for the near-field flow and transport model refer to discussions on the information need level; specific activities for these input parameters are described in the information need discussions.

[b]TSw2 = welded Topopah Spring Member.

Table 8.3.4.2-2. Performance measures and goals for Issue 1.10 (waste package characteristics--postclosure)

System element	Performance measure	Tentative goal	Needed confidence
Engineered environment	Quantity of liquid water that can contact the container	See Issue 1.4 (Table 8.3.5.9-1 Section 8.3.5.9)	
	Quality of liquid water than can contact the container	See Issue 1.4 (Table 8.3.5.9-1 Section 8.3.5.9)	
	Rock-induced load on waste package	Container will not fail when subjected to design basis loads	High
	Temperature vs. time in waste package environment	See Issue 1.11 (Table 8.3.2.2-4, Section 8.3.2.2)	
	Tectonic processes	<0.5% of containers breached	High
Waste package	Select waste package material to contribute to containment	See Issue 1.4 (Table 8.3.5.9-4, Section 8.3.5.9)	
	Constrain waste-handling operations so as not to degrade isolation and containment performance of the waste package	See Section 8.3.2.5	

Table 8.3.4.2-3. Performance parameters and goals for Issue 1.10 (waste package characteristics--postclosure)

Performance measure	Performance parameter	Tentative goal	Needed confidence	Expected parameter value	Current confidence
Rock-induced load on waste package	Load on waste package	<1,000 kg/pkg for 1,000 yr <3,000 kg/pkg between 1,000 and 10,000 yr	High	TBD[a]	
Tectonic processes	Breaching of containers by tectonic processes	<0.5% containers breached	High	See Section 8.3.1.8	

[a]TBD = to be determined.

quality of the waste package environment (Section 8.3.4.2.4.1), the post emplacement hydrologic features of the waste package environment (Section 8.3.4.2.4.2) and the postemplacement thermal and mechanical properties of the waste package environment (Section 8.3.4.2.4.3). These characterization activities are required to address performance parameters identified in Issues 1.4 and 1.5. The specific performance parameters, their respective characterization parameters and test bases, and the SCP section describing the activity that addresses each characterization parameter are presented in Table 8.3.4.2-4.

The characterization parameters pertaining to water quality reflect the goal that the chemical characteristics of the water will be similar to those existing in the undisturbed environment in the unsaturated Topopah Spring tuff at Yucca Mountain. The characterization constraints are established because water chemistry is a very sensitive parameter in determining corrosion rates and mechanisms for metals and because changes in water chemistry strongly influence the rock-water interaction and hydrologic properties of the tuff. Typical values for water found below Yucca Mountain are discussed in Section 7.4.1.

The quantity of water that contacts containers is constrained as part of the design strategy to meet the containment and release rate performance objectives established in Issues 1.4 and 1.5. The parameters to be evaluated in meeting this goal concern the hydrologic characteristics of the repository site, which control the rate at which water can be expected to move through the rock.

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 1 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5)	Water quality	Vadose water		8.3.4.2.4.1.3
		pH	±1 (1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	
		Cations present at >40 mg/L	±20 mg/L (1)	
		Rock-water interaction		8.3.4.2.4.1.1
		pH	±1 (1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 2 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Rock-water interaction (continued)		
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	
		Cations present at >40 mg/L	±20 mg/L (1)	
		Temperature	±5°C	
		Composition of solid reactants and products	±10 wt% of elemental abundance for those elements that comprise more than 5 wt% of minerals analyzable on the electron microprobe	
		Reactant surface area	±20% for BET[b] surface area measurements	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 3 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Rock-water interaction (continued)		
		Modal abundance of solid reactants and products	±20% for optically identifiable phases	
		Dissolution and precipitation		8.3.4.2.4.1.4
		pH	±0.5 (1)	
		Mineral composition	±10 wt% of elemental abundance for those elements that comprise more than 5 wt% of minerals analyzable on the electron microprobe	
		Composition of product fluid	±10% for those elements that constitute more than 10% (atomic) of the mineral phase	
		Mineral structural state	±20% for the degree of disorder in the crystal lattice	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 4 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Repository materials effect on water chemistry		8.3.4.2.4.1.2
		pH	±1 (1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	
		Cations present at >40 mg/L	±20 mg/L (1)	
		Temperature	±5°C	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 5 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Repository materials effect on water chemistry (continued)		
		Composition of solid reactants and products	±10 wt% of elemental abundance for those elements that comprise more than 5 wt% minerals analyzable on the electron microprobe	
		Reactant surface area	±20% for BET surface area measurements	
		Modal abundance of solid reactants and products	±20% for optically identifiable phases	
		Radiation effects		8.3.4.2.4.1.5
		Temperature	±5°C	
		Radiation dose rate	0-100 krad/h	
		Degree of water saturation in experiment atmosphere	±20%	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 6 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Radiation effects (continued)		
		Nature of solid materials	Chemicals and structural characterization of material sufficient to allow fluid and gas composition to be experimentally reproduced to within ±20%	
		pH	±1 (1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 7 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Radiation effects (continued)		
		Cations present at >40 mg/L	±20 mg/L (1)	
		Formate ions	±30% (1)	
		Oxalate ions	±30% (1)	
		HNO_3	±20% (1)	
		Nitrite: nitrate ratio	±30% (1)	
		CO_2	±20% (g)	
		O_2	±20% (g)	
		NO_x	±20% (g)	
		N_2	±20% (g)	
		NH_3	±30% (g)	
		Corrosion products		8.3.4.2.4.1.6
		Temperature	±5°C	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 8 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Corrosion products (continued)		
		Composition and mineralogy of corrosion products	Chemical and structural material characterization sufficient to allow fluid and gas composition parameters to be experimentally reproduced to within ±20%	
		Degree of water saturation in experiment atmosphere	±20%	
		pH	±1 (1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 9 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Corrosion products (continued)		
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	
		Cations present at >40 mg/L	±20 mg/L (1)	
	Water quantity	Single-phase fluid		8.3.4.2.4.2.1
		Nature of fluid phase	Liquid or gas	
		Number of rehydration and dehydration cycles	Number of cycles must be sufficient to attain steady state permeability	
		Temperature	±5°C	
		Relative permeability	±20%	
		Fracture permeability	±20%	
		Degree of saturation	±50%	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 10 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quantity (continued)	Single-phase fluid (continued)		8.3.4.2.4.2.1
		Resistivity	±15%	
		Magnitude of thermal gradient	±20%	
		Two-phase fluid flow		8.3.4.2.4.2.2
		Number of rehydration and dehydration cycles	Number of cycles must be sufficient to attain steady state permeability	
		Temperature	±5°C	
		Relative permeability	±20%	
		Fracture permeability	±20%	
		Degree of saturation	±50%	
		Resistivity	±15%	
		Magnitude of thermal gradient	±20%	
		Gas: liquid ratio	±20%	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 11 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Thermal loading	Near-field temperature distribution		8.3.4.2.4.4.3
		Thermal properties (initial temperature, heat capacity, thermal conductivity) for TSw2 as identified in Section 8.3.2.2 (Issue 1.11, configuration of underground facilities (postclosure))	See Table 8.3.2.2-5	8.3.2.2
		Package emplacement geometry	TBD[c] by repository design	8.3.2.2.6
		Package spacing	TBD by repository design	8.3.2.2.6
		Heat output of waste packages	TBD by package design, Issue 2.6	8.3.5.10.1
	Rock-induced loading	Near-field stress distribution and rock displacements		8.3.4.2.4.3.1

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 12 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Rock-induced loading (continued)	Near-field stress distribution and rock displacements (continued)		
		Mechanical properties (Young's modulus, Poisson's ratio, compressive strength, etc.) for TSw2 as identified in Section 8.3.2.2 (Issue 1.11)	See Table 8.3.2.2-5	8.3.2.2
		Fracture (joint) characteristics (shear and normal stiffness, orientation, frequency, etc) for TSw2 as identified in Section 8.3.2.2 (Issue 1.11)	See Table 8.3.2.2-5	8.3.2.2

[a]Unless otherwise stated, the specified percentages and plus-and-minus values are characterization goals that indicate the maximum experimental uncertainty for measurements of the indicated parameter. (l) indicates species in the liquid phase, (g) indicates species in the gas phase.

[b]BET = Brunauer-Emmett-Teller.

[c]TBD = to be determined.

The borehole stability and thermal loading constraints concern engineering practices that influence the integrity of the waste package. In addition, the thermal loading goals provide for an environment for a large fraction of the waste packages that will be above the boiling point of water for the period of time indicated in Issue 1.4 (Section 8.3.5.9). This goal contributes to the strategy to meet the release rate performance objective.

As part of the issue resolution strategy, a design envelope for the waste package has been developed. This envelope is based on present knowledge of the site characteristics (with due consideration for the associated uncertainties and for the range to be determined for anticipated processes and events) and on the known properties of the waste forms (Chapter 7). Activity 1.5.3.1, scenarios, will determine whether the design envelope encompasses the near-field conditions developed due to interactions with all anticipated processes and events. In the following eight sections (A through H), the design envelope is described and the goals for characterization, design, or performance of each part of the design envelope are discussed. Some of these goals provide characterization goals for, or constraints on, other issues.

A. The emplacement hole geochemical system

The characteristics of the host rock mineralogy and chemistry have been established by study of surface outcrop and drill core samples of Topopah Spring tuff located around the exploratory block. The welded, devitrified Topopah Spring tuff from the level of the potential repository shows little variation in chemistry. Because of the limited degree of variability expected in rock chemistry and mineralogy and the need for detailed characterization of the rock (Section 8.3.1.3), additional characterization goals related to rock chemistry are not needed.

Currently, the reference water chemistry is based on water from well J-13, which is located east of the repository block. This well was chosen because of the similarity of its water chemistry to that found in water below the exploratory block. Samples of vadose water from the repository horizon have not yet been obtained. Since the water chemistry plays a critical role in determining the performance of the waste package components, it is necessary to set a goal for the degree of characterization of water chemistry to be accomplished during site characterization. The test bases (or degree of characterization needed for this issue) for the water chemistry characterization parameters will be accomplished in the geochemistry program (8.3.1.3). These test bases are specified to establish the mean value of water chemistry parameters so that the standard deviation of the mean is no greater than the values given in the following list (note that this establishes only how well the mean value must be known; it does not constrain what the value must be). The bases for the limits were the effects of each of the parameters on waste package component performance.

Characterization goal for water chemistry. The characterization parameters for water chemistry are identified in Table 8.3.4.2-4 along with their test bases (or degree of characterization needed) for this issue. The characterization parameters and test bases for the geochemistry program follow:

Characterization parameters	Test basis
pH:	±1 pH unit
Anions:	±1 mg/L for F^-, Cl^-, PO_4^{3-}
	±5 mg/L for NO_3^- and SO_4^{2-}
	±30 mg/L for CO_3^{2-} plus HCO_3^-
	±1 mg/L for all other anionic species

Characterization parameters	Test basis
Cations:	±1 mg/L for species present at less than 6 mg/L
	±5 mg/L for species present at 6 to 40 mg/L
	±20 mg/L for species present at over 40 mg/L
Colloids:	±1 mg/L
Organics:	±1 mg/L
Neutral species:	±1 mg/L

The numerical values for these test bases are established so that they are analytically achievable and are sufficiently constrained so that they do not introduce large uncertainties into the metals and waste form testing results.

The pH is important because of the sensitivity of glass dissolution rates, actinide solubility and speciation, and metal corrosion mechanisms to pH. Fluoride and chloride are deleterious to metal performance, and phosphate can be corrosive to glass; therefore, their abundance in water must be well characterized. Carbonate and bicarbonate are beneficial in that they buffer the pH of the water but are detrimental in that they can form complexes with actinides. A moderate level of precision is needed for these species. Colloids and organic materials may significantly affect transport properties of radionuclides; therefore, a high level of precision is required. Other elements are needed to provide a complete analysis so that charge balance calculations can be used to evaluate the quality of the analysis.

If the site is found to be laterally inhomogeneous to the extent that the characterization goals cannot be met for the site considered as a single unit, the site will be separated into regions for which the characterization goals will apply.

B. The emplacement hole and near-field hydrologic system

The characteristics of the hydrologic system at Yucca Mountain will be determined in the geohydrology program (Section 8.3.1.2). A discussion of the expected hydrologic system in the unsaturated zone is provided in Chapters 3 and 7. Further studies will be conducted under activities described in Information Need 1.5.5 (Section 8.3.5.10.5). The hydrologic parameters that are most important to waste package design and performance are the percolation rate of water through the repository horizon and the flow paths for the water. Of particular interest are the proportion of the flow that occurs in fractures and the variation of the proportion of fracture flow as a function of percolation rate.

Studies will be conducted under activities described in Information Need 1.10.4 (Section 8.3.4.2.4.4) that will characterize the hydrology of the waste package environment. This characterization will establish the extent to which the near-field hydrologic system will contribute to meeting the performance goal set in Issues 1.4 and 1.5 for amount of water that can contact a waste container.

The heat associated with the waste package will perturb the near-field flow paths. Studies to investigate the amount of perturbation and its effects are described in Information Need 1.10.4 (Section 8.3.4.2.4).

The construction of the repository may alter the local hydrologic system. This alteration might be caused by disturbance of the rock mass, the introduction of water during construction, dehydration of the rock mass through use of ventilation systems, or other causes. Some of these alterations could be beneficial to waste package performance; others could be detrimental.

Because of the importance of water volumes, flow paths, and flow rates in the assessment of waste package performance, performance goals for the near-field hydrologic system have been set in Issues 1.4 and 1.5. The goals that are set for an individual waste package are based on a conservative estimate of the amount of water that could contact the ensemble of waste packages in a given year. The goals apply to anticipated processes and events.

The goals for the amount of water contacting waste packages are based on a conservative upper bound of current percolation rate through the repository horizon (i.e., 0.5 mm/yr (Montazer and Wilson, 1984) and a factor of additional conservatism. (The same upper bound value is selected in Table 8.3.5.13-9 for Scenario Class E, normal case, which includes natural events reasonably likely to occur in the 10,000-yr period.) At the 0.5-mm/yr flux, 0.23 L/yr is approximately the annual quantity of water that would pass vertically through the projected area above a 76-cm-diameter, vertical emplacement borehole. Similarly, 1.5 L/yr is the annual quantity of water that would pass vertically through the projected area of a 4-m-long (typical size) horizontally emplaced waste package. Actually, for either emplacement mode the water is likely to be diverted around the opening and conducted through the rock. Applying a factor for added conservatism, one obtains an annual volume of 5 L passing through that projected area. Other values,

either more or less conservative, may be obtained by similarly scaling the volumetric flow of 0.25 L/yr.

Note that these goals on the quantity of water contacting the waste packages are applied without considering whether the water could actually enter the borehole. In an unsaturated host rock, water would not normally enter a borehole unless a saturated region had formed above the borehole, large enough in the vertical direction to provide pore pressures sufficiently high to overcome the capillary pressures at the borehole surface. This condition is not currently anticipated in the unsaturated zone of the repository horizon.

Further, the quantitative values of these factors and the corresponding annual amounts of water are not intended to correspond to either saturated or unsaturated flow conditions. They are intended to provide guidance for the required performance of repository seals for anticipated processes and events. In addition, based on present knowledge of the hydrology of Yucca Mountain, these values are sufficiently large to compensate for uncertainties in our current level of understanding of the unsaturated zone at the repository level.

Analyses conducted under Issue 1.11 (Section 8.3.2.2) will determine if the goals have been achieved. Note that the water volumes allowed for long-term water control greatly exceed those expected based on the current estimates of upper bounds on percolation rates through the repository horizon.

Design goal for water flux control. The repository will be designed and constructed so that, for anticipated processes and events, the following conditions will be met with a high level of confidence:

1. There will be no liquid water in the emplacement borehole immediately before emplacement of the waste package, and conditions will be such that no liquid water can contact the waste package during the period from package insertion until repository closure.

2. For the first 300 yr after repository closure, no liquid water will contact 95 percent of the waste packages, and less than 5 L per package per year will contact the remaining 5 percent.

3. During the period from 300 to 1,000 yr after repository closure, no liquid water will contact 90 percent of the waste packages, and less than 5 L per package per year will contact the remaining 10 percent.

4. During the period from 1,000 to 10,000 yr after repository closure, no liquid water will contact 90 percent of the waste packages, and less than 20 L per package per year will contact the remaining 10 percent.

C. Emplacement hole drainage

The previous section discusses the design goals for water contacting waste packages in a given year. These goals were based on water influx. It is also necessary to determine if water entering the borehole can drain at a

sufficient rate to ensure that standing water does not accumulate. The use of a borehole liner might influence drainage in two ways. First, corrosion products from the liner might be flocculent and lead to plugging of the rock pores, thereby decreasing permeability of the rock matrix. Second, for a vertical borehole, a liner with an unperforated bottom plate would totally block drainage. For a horizontal emplacement hole, a liner placed in a hole that was not sufficiently inclined to promote drainage might lead to local accumulations of standing water. Another factor that might alter the drainage capability of emplacement boreholes is the choice of drilling method.

The accumulation of standing water in boreholes would lead to deleterious effects on the waste package performance. For that reason, as part of the performance allocation process, a design goal for drainage from the boreholes has been set. The analyses to show that this goal has been met are described under Issue 1.11 (Section 8.3.2.2).

Design goal for drainage of emplacement boreholes. The borehole and its engineered components, such as liners, shall be designed and constructed so that for anticipated processes and events, the following conditions will be met with a high level of confidence:

1. The borehole will not fill with standing water under anticipated conditions at any time up to 10,000 yr following repository closure.

2. For the first 1,000 yr following repository closure, no more than 5 L of standing water per waste package will accumulate in emplacement boreholes.

D. Emplacement hole configuration and stability

The configuration of the emplacement boreholes is important in developing scenarios for waste package container degradation and subsequent radionuclide release rate analysis. For a horizontal emplacement configuration, one can envisage some conditions in which water could drip from a fracture onto a waste package. For a vertical borehole, this scenario seems very unlikely since the borehole plug will shield the package from dripping water.

The emplacement hole configuration may also affect the stability of the borehole and be a deciding factor in whether it will be necessary to use a borehole liner. As discussed previously, the liner can affect drainage from the borehole. The liner could also produce interactions with the waste package; this concern is discussed later under item H.

The need for information on the emplacement hole configuration will be met by close interaction between the repository and waste package designers (Information Need 1.10.3, Section 8.3.4.2.3). It is necessary to set a goal to establish what rock-induced loads must be borne by the waste package. Analyses to determine that the borehole stability meets the goal are conducted under Information Need 1.10.4 (Section 8.3.4.2.4) as shown in Tables 8.3.4.2-2 and 8.3.4.2-3. Inspection of the repository for fault and shear zones will be established by Issue 1.11 (Section 8.3.2.2). The question of what size shear zones must be found to ensure less than 5 cm displacement

(accommodated by air gaps in the borehole) in the 1,000 yr after closure will be addressed in the Site Program 8.3.1.8 (postclosure tectonics).

Design goal for rock-induced load on the waste package. The emplacement hole will be designed and constructed so that the following conditions will be met with a high level of confidence:

1. Less than 0.5 percent of the containers will be breached by anticipated tectonic processes and events during the first 1,000 yr after closure. Drifts and boreholes will be inspected for fault and shear zone, and waste packages will not be emplaced across such regions.

2. For 1,000 yr after closure, the stability analysis will show with a high level of confidence that the rock-induced load on a waste package will be less than 1,000 kg.

3. For 10,000 yr after closure, the stability analysis will show with a moderate level of confidence that the rock-induced load on a waste package will be less than 3,000 kg.

4. Emplacement boreholes will be cleaned of debris before use.

E. Thermal loading of the waste package and the repository layout

The thermal loading of the waste package and the repository layout are interactive parameters. It may be necessary to vary the loading per package and the number of packages per unit area of repository to achieve the desired thermal effects. Thermal loadings that keep the waste package near-field environment above the boiling point of water will assist in achieving the goal set for the amount of water that can contact the waste packages. On the other hand, the thermal loadings must be kept sufficiently low so that waste form temperature limits are not exceeded. These temperature limits are based on the waste form properties and were set to limit degradation of the waste form performance from thermal transients in the early stage of repository history.

The primary information needed to design thermal loadings is the power output of the waste form. Most of the waste that will go into the repository has not yet been generated. Extrapolations of waste age, spent fuel burnup, and other parameters are necessarily uncertain. The design goal for thermal loading is based on two concepts. The first is to maintain adequate flexibility to allow for the uncertainties. The second is the setting of a characterization goal. This goal, combined with a flexible repository layout, will allow the thermal loading during the operational stages of the repository to achieve the desired thermal effects.

Design goal for thermal loading. The design goals for thermal loading include the following:

1. The repository layout will be designed so that the thermal loading characteristics will assist in keeping liquid water from contacting

the waste packages for the first 300 yr after closure. It will also ensure that the design-limit temperatures for waste forms are not exceeded.

2. The waste forms will be characterized sufficiently well so that the radionuclide inventory at the time of emplacement will be known to within ±20 percent for each nuclide that represents 5 percent or more of the radioactivity in the packages at any time during the first 1,000 yr after emplacement.

The information to show that part 1 of the goal is met is developed in the resolution of Issue 1.11 (Section 8.3.2.2); part 2 is addressed in Section 8.3.5.10.1 under Information Need 1.5.1.

F. Waste package container material

The selection of the material from which to fabricate the waste package container is important for a variety of reasons. The material choice may be a factor in meeting the performance objective for the containment period and may affect the radionuclide source term for total system performance assessment. The issues related to long-term performance of the container material are discussed under Issue 1.4 (Section 8.3.5.9). This section discusses those aspects of container selection that influence the chemistry of the near-field environment and that influence the design of the waste package.

The effect of the container material on the near-field environment is through the interaction of container corrosion products with the environment. The corrosion rate for the material is determined under Issue 1.4 (Section 8.3.5.9); the effect of the corrosion products on water chemistry is evaluated under Information Need 1.10.4 (Section 8.3.4.2.4). To limit the volume of the corrosion products to be considered, a design goal on the rate of material loss caused by uniform corrosion has been set. The goal is set to provide information on the geometry of the container needed for use in resolving Issue 1.5 (Section 8.3.5.10).

The material choice influences waste package design through a number of considerations, which are evaluated under Information Needs 1.4.1, 1.4.2, and 1.4.3 (Section 8.3.5.9). First, the uniform corrosion rate establishes a minimum thickness of metal for the container. Second, mechanical properties of the container material determine some of the design parameters such as thickness, handling-device shape, and contours of the container. To allow for these considerations, a design goal has been established for the container material.

Design goal for the container material with respect to waste package design and environmental concerns. The container material will be selected so that the following conditions are met with a high level of confidence.

1. The container material will have mechanical properties such that the container will not fail due to mechanical causes when subjected to design basis loads under anticipated conditions for 1,000 yr.

2. The container material will have degradation rates by uniform oxidation and uniform corrosion so that no more than 90 percent of the

container wall thickness will be removed by these mechanisms over the first 10,000 yr following repository closure.

The rationale for those conditions and the analyses required to show that these goals will be met are discussed in Section 8.3.5.9 (Information Needs 1.4.1, 1.4.2, and 1.4.3).

Goals for the container material that relate to meeting the containment period performance objective are discussed in Section 8.3.5.9.

G. Waste package fabrication and handling before emplacement

The waste package container material must be capable of being fabricated to design specifications in a reliable manner. The final closure for the container must be capable of being made and inspected under remote operating conditions, with a high level of confidence that defective closures will be detected. The fabrication and closure processes must not degrade the performance of the container material in ways that will preclude meeting the performance objectives discussed under Issue 1.4 (Section 8.3.5.9).

Design goal for fabrication. The fabrication process for the body of the container, including the unique container identification, will not cause an increase in the degradation rate of the material by a corrosion process that might operate in the repository to levels that would cause the performance goals set under Issue 1.4 (Section 8.3.5.9) not to be met.

Design goal for closure. The closure process will be capable of being done and inspected under remote conditions with a reliability such that the container would be capable of passing a standard helium leak test at the level of 1×10^{-7} atm-cm^3/s. The level of undetected defective closures will be shown to be less than 1 percent.

Analyses to show that these goals will be met are discussed under Information Need 1.10.2 (Section 8.3.4.2.2).

Design goal for handling. The surface-handling and emplacement operations might cause damage to the container. To limit such damage, care must be taken during the loading of the container, the closure of the container, any surface-handling and storage operations, and emplacement of the container into the repository.

To avoid damage from handling that affects performance, the following conditions are set:

1. The container will not be allowed to contact corrosive chemicals during the surface-handling and emplacement operations except as needed for surface finishing.

2. Any container that is subjected to an impact load equivalent to a free fall of 10 cm or more during handling will not be emplaced. The 10-cm free-fall condition is tentative.

3. Any container that is scratched so that the metal is thinned by 1 mm or more will not be emplaced.

4. Any container that has experienced an unusual process history that would cause new corrosion considerations to arise will not be emplaced.

These conditions are based on the criterion that the containment function of the waste package will be preserved during handling. The conditions are established to be achievable within the surface facility and repository setting.

H. Alteration to the environment caused by nonwaste package components

One of the largest areas of uncertainty and concern with respect to the package design envelope is the effect of repository construction materials on the local environment of the packages. To remove some of the uncertainties, as part of the performance allocation process, some limits have been established on the allowed effects on the environment from repository construction. These limits can generally be met by suitable choice of construction materials. In some instances, materials with undesirable effects on the vadose water chemistry can be used, as long as it can be shown that the affected water cannot contact a waste package.

The immediate vicinity of the waste package will be influenced by the choice of borehole liner material. Thus, two design goals for the liner material have been set. The other materials that might be present in sufficient quantities to cause major changes to water chemistry are the grout and concrete-type materials used for ground supports and for sealing shafts and boreholes. For vertical emplacement, either a specially designed material will be needed or a hole plug design that does not use conventional grout or concrete will have to be used. (Conventional grouts and concretes result in a very high water pH, which is unacceptable from the point of view of long-term waste form performance.) For horizontal emplacement, conventional materials might be adequate, provided that the hydrologic system is sufficiently well understood to show that the grout-affected water cannot contact waste packages.

Two design goals were set for the borehole liner, and a single unified design goal was set for the alterations to water chemistry for water that might encounter waste packages.

Design goals for the borehole liner. The two design goals for the borehole liner are as follows:

1. The corrosion rate of the borehole liner by uniform corrosion will be within a factor of 2 of that for the container material. This will be demonstrated in analyses done under Information Need 1.4.2 (Section 8.3.5.9.2).

2. The borehole liner shall be a member of the same alloy family as the container material (i.e., if the container material is an austenitic stainless steel, then the liner will also be an austenitic stainless

steel). The liner material used in repository designs will reflect this requirement for compatibility (Issue 1.11, Section 8.3.2.2).

These goals are established to avoid significant galvanic effects between the container and borehole liner and to avoid generation of colloids.

Design goal for alteration of water chemistry. Repository engineered barriers and shaft and borehole seals will be designed and constructed so that the changes in water chemistry resulting from interaction of those materials with the vadose water (characterized earlier under item A) for water that might contact a waste package will be within the limits established in Issue 1.4. Analyses to show that this has been achieved are given in resolution of Issues 1.11 (Section 8.3.2.2) and 1.12 (Section 8.3.3.2).

Limits to alteration of water chemistry. Interactive effects between ions in solution and the consequences of these interactions for container and waste form performance require that limits be placed on the extent to which the concentration of certain species may be modified by repository construction materials. The numerical values for these limits are as follows:

Characterization parameters	Test basis
pH:	± 1pH unit
Anions:	+1 mg/L for F^-, Cl^-, and PO_4^{3-}
	+10 mg/L for NO_3^- and SO_4^{2-}
	+50 mg/L for CO_3^{2-} plus HCO_3^-
	+1 mg/L for all other anionic species

Characterization parameters	Test basis
Cations:	+1 mg/L for species present at less than that level in the vadose water
	+10 mg/L for CA^{++}, K^+, and Mg^{++}
	+30 mg/L for Na^+
	-5 mg/L for Si^{4+}, no limit to increase
Colloids:	+1 mg/L
Organics:	+1 mg/L
Neutral species:	+1 mg/L

Interrelationships of the information needs

This issue involves development of the reference waste package designs and determination of the effect of those designs on the waste package environment. It also involves establishing that the designs comply with the requirements of 10 CFR 60.135. Because this latter item involves a specific set of requirements, it has been cast as a separate Information Need 1.10.1 (Section 8.3.4.2.1).

The reference waste package designs will be developed from a consideration of our understanding of the service environment. As such, Information Needs 1.10.2 (Section 8.3.4.2.2) and 1.10.4 (Section 8.3.4.2.4) are interactive. Information Need 1.10.3 (Section 8.3.4.2.3) relates to the emplacement configuration. It has been cast as a separate information need to highlight the uncertainties associated with the present situation, which includes both vertical and horizontal emplacement as options, and to facilitate issue resolution when the final emplacement mode is chosen.

When the emplacement mode is chosen, and when the waste package design is completed, the analyses required to satisfy Information Needs 1.10.1 (Section 8.3.4.2.1) and 1.10.4 (Section 8.3.4.2.4) will be performed. The results of these analyses, if favorable, will resolve the issue.

The schedule information for Issue 1.10 (waste package characteristics--postclosure) is presented in Section 8.3.4.2.5.

8.3.4.2.1 Information Need 1.10.1: Design information needed to comply with postclosure criteria from 10 CFR 60.135(a) for consideration of the interactions between the waste package and its environment

Technical basis for addressing the information need

The general design criteria contained in 10 CFR 60.135(a) are stated in the context of the in situ properties of the waste package and the interactions between the package and its emplacement environment. These properties and interactions are evaluated to ensure that the function of the waste packages, the performance of the underground facility, or the geologic setting is not compromised.

The criteria require that the design consider a number of factors relating to the performance of the waste packages and their interaction with the environment. The basis for addressing this information need will be to show that the relevant factors have been evaluated in the design.

Link to the technical data chapters and applicable support documents

The work that has been undertaken to date to characterize the performance of the waste package components and the interactions of the waste packages with the near-field environment is discussed in Chapter 7. Specifically, Section 7.4.1 describes the examination of the ambient environment and the changes induced by the introduction of the waste packages. Sections 7.4.2 and 7.4.3 describe the examinations of the performance of the

package components under conditions representative of those expected in the repository.

Parameters

The parameters associated with this information need are the relevant postclosure properties and interactions that are stated in 10 CFR 60.135(a)(2) as factors to be considered and include the following:

1. Solubility.
2. Oxidation-reduction reactions.
3. Corrosion.
4. Gas generation.
5. Thermal loads and effects.
6. Mechanical strength and stress.
7. Radiolysis and radiation damage.
8. Radionuclide retardation and leaching.
9. Synergistic interactions.

Interactions and coupled effects involving some of these parameters are also discussed in Section 8.3.2.1.

Logic

The logic to be used in addressing this information need is basically one of integration. The information is developed within other information needs, where the nature of the in situ properties of the waste package and the interactions of the package with the near-field environment are characterized and analyzed.

8.3.4.2.1.1 Design Activity 1.10.1.1: Consideration of 10 CFR 60.135(a) factors

Objectives

This activity will explicitly show that the factors specified in 10 CFR 60.135(a) and listed as parameters for this information need have been considered in the waste package design. The evaluation will identify those factors that could potentially compromise the function of the waste package, the performance of the underground facility, or the geologic setting.

Parameters

The parameters for this activity are given in the list for the information need.

Description

The information to be used in the evaluation will be derived from the studies undertaken in other information needs. Specifically, the information to show that the factors that could potentially compromise the function of the waste package have been considered will be included in the performance

analyses done in Information Need 1.4.5 (Section 8.3.5.9.5) and 1.5.4 (Section 8.3.5.10.4). The information to show that the interactions of the package with emplacement environment have been considered will be taken from the studies done in Information Need 1.10.4 (Section 8.3.4.2.4).

8.3.4.2.1.2 Application of results

The results of the analysis done under this information need will be used to show explicitly that the factors enumerated in the regulation have been considered in the design and that the properties and interactions meet the requirements for not compromising the waste package functions, performance of the repository, or geologic setting. This analysis will then directly contribute to the resolution of this issue (1.10).

8.3.4.2.2 Information Need 1.10.2: Reference waste package designs

Technical basis for addressing information need

Link to the technical data chapters and applicable support document

Conceptual waste package designs are described in Section 7.3. These designs have been developed during the conceptual design phase and include both reference designs (Section 7.3.1) and alternative designs (Section 7.3.2).

Parameters

The parameters that require documentation to fulfill this information need are in two categories: (1) physical characteristics and (2) output characteristics. The parameters are required for all waste forms planned for packaging and disposal. They include the variations in the characteristics that will occur as a result of both the inherent range of waste forms to be accommodated and the anticipated time-dependent variations over the operating life of the repository.

The physical characteristics include

1. Number of packages of each type as a function of time.

2. Internal and external configurations of the packages, with dimensions and tolerances.

3. Package weights and weight distributions.

4. Mechanical and thermal properties of the package component materials.

The output characteristics include

1. Decay-heat generation rates of the waste packages.

2. Ionizing radiation fluxes at the external surfaces of the packages.

Logic

The principal purpose of this information need is to provide a source of reference (and alternative) waste package design data that is traceable to the Yucca Mountain Project technical baseline for use in the analysis of the projected performance of the engineered barrier system. In addition, the waste package characteristics are needed to support the definition of appropriate materials testing environments, both at laboratory and in situ scales, and to provide design input to the repository facilities, equipment, and operations design activities.

This information need does not require site characterization studies, tests, or analyses. The design information that is collected under this topic is developed as an integral part of the design process. A substantial portion of the information that supports the design process is baselined at the Office of Civilian Radioactive Waste Management Program level. Other baselined input is controlled at the Yucca Mountain Project level in the technical baseline. The detailed waste package design studies and analyses will be documented in the advanced conceptual and license application design reports. Interim design information will be maintained and controlled in the Yucca Mountain Project reference information base.

8.3.4.2.2.1 Application of results

The reference (and alternative) waste package design information will be used in Issues 1.4 and 1.5 (Sections 8.3.5.9 and 8.3.5.10) to provide the configurations and output characteristics to be used in the analyses of the postclosure performance of the waste packages and the engineered barrier system. In addition, the information will be used in support of the repository design in Issues 1.11 and 2.7 (Sections 8.3.2.2 and 8.3.2.3). Within this issue, the waste package design information, in combination with the emplacement configuration information described in Information Need 1.10.3 (Section 8.3.4.2.3), will be used to determine the near-field temperature history for the waste packages.

8.3.4.2.3 Information Need 1.10.3: Reference waste package emplacement configurations

Technical basis for addressing information need

Link to technical data chapters and applicable support documents

The waste emplacement configurations within the repository subsurface facilities that have been considered during the conceptual design phase are described in Chapter 6. The reference for the conceptual design is vertical emplacement of the waste packages in holes constructed in the floor of the emplacement drifts, with a single package installed in each hole. An alternative configuration, with multiple packages emplaced within a single horizontal hole, has also been considered.

In addition to the orientation of the emplacement holes, other details of the configuration need to be determined. The distribution of the thermal output of the waste forms is an important consideration that is necessary to assess the performance of the waste packages and the engineered barrier system. In addition, the physical distribution of the emplaced waste packages is determined by the spacing of the emplacement drifts, the pitch (spacing) of the holes, the dimensions of the holes, and the position of the waste packages within the holes. The conceptual designs of these elements for both emplacement orientations are also described in Chapter 6.

Some of the effects of the emplacement configuration on the performance of the waste package components are discussed in Sections 7.4.2 and 7.4.3.

Parameters

The parameters that require determination to fulfill this information need are in two categories: (1) physical characteristics and (2) output characteristics. The parameters are required to include the variations in the characteristics that will result from the types of waste packages to be emplaced and the anticipated time-dependent variations in package thermal output at the time of emplacement during the operating life of the repository.

The physical characteristics include

1. Emplacement orientation: vertical or horizontal.

    a. For vertical boreholes:

        i. Borehole diameter.

        ii. Borehole depth.

        iii. Configuration of other emplacement hole components (e.g., liners and shielding plugs).

b. For horizontal boreholes:

i. Borehole diameter.

ii. Borehole length.

iii. Package spacing in hole.

iv. Standoff distance from drift to package.

v. Configuration of other emplacement hole components (e.g., liners and shielding plugs).

2. Emplacement drift layout and dimensions.

3. Emplacement borehole spacing (pitch).

The output characteristics include

1. Planned spatial distribution by waste package types.

a. Spent fuel.

b. Glass waste forms from West Valley Defense Project and Defense Waste Processing Facility.

2. Planned spatial distribution by waste package thermal power during repository operating life.

Logic

The principal purpose of this information need is to provide a source of reference (and alternative) repository configuration design data that is traceable to the Yucca Mountain Project technical baseline for use in the analyses of the projected performance of the waste packages and the engineered barrier system. In particular, this information, together with the thermal and hydrologic properties of the host rock, will determine the near-field temperature distribution as a function of time. In addition, the emplacement configuration characteristics are needed to support the definition of appropriate materials testing environments, both at laboratory and in situ scales, and to provide design input to the waste package design activities.

This information need does not require site characterization studies, tests, or analyses within this issue. The design information collected under this topic is developed as an integral part of the repository design process and is controlled in the Yucca Mountain Project technical baseline. The detailed design studies and analyses will be documented in the advance conceptual and license application design reports. Interim design information will be maintained and controlled in the Yucca Mountain Project reference information base. The design studies and analyses to determine the repository configuration characteristics are described in Section 8.3.2 (Issues 4.4 and 1.11).

8.3.4.2.3.1 Application of results

The reference (and alternative) emplacement configuration design information will be used in Issues 1.4 and 1.5 (Sections 8.3.5.9 and 8.3.5.10) to provide the configuration used in the analyses of the postclosure performance of the waste packages and the engineered barrier system. Within this issue (1.10), the emplacement configuration information, in combination with the waste package design information described in Information Need 1.10.2, will be used to determine the near-field temperature distribution as a function of time for the waste packages. The information will be used as a part of the design basis for the waste package design in Issue 2.6 (Section 8.3.4.3).

8.3.4.2.4 Information Need 1.10.4: Postemplacement near-field environment

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The following sections of the data chapters provide a technical summary of existing data relevant to this information need:

SCP section	Subject
7.1	Emplacement environment
7.4.1.1	Stability of borehole openings
7.4.1.2	Anticipated thermal history
7.4.1.3	Reference water for laboratory studies
7.4.1.4	Radiation field effects
7.4.1.5	Thermal effects on water flow in the vicinity of waste packages
7.4.1.6	Numerical modeling of hydrothermal flow and transport
7.4.1.7	Rock-water interaction
7.4.1.8	Modeling rock-water interaction

The technical data discussed in these sections describe attributes that will influence the thermal history of the repository and establish the extent of chemical interaction expected in the waste package environment. Further work to address remaining uncertainties discussed in Sections 7.4.1.1, 7.4.1.3, 7.4.1.4, 7.4.1.5, 7.4.1.6, and 7.4.1.7 is outlined in Section 8.3.4.2.4.2.

Parameters

The following parameters will be measured or calculated as a result of the studies planned to satisfy this information need:

1. Near-field thermal history.

2. Postemplacement changes in the near-field mineralogy and fluid chemistry: volumes and compositions of mineralogical and fluid reaction products formed in hydrothermal tests, as a function of temperature, time, fluid composition, and radiation dose. Modeling of the laboratory systems will be carried out for purposes of code validation.

3. Postemplacement, near-field hydrologic properties: definition of the hydrologic properties of representative repository horizon rock, including characteristic curves for single- and two-phase systems, flow pathways in intact and fractured rocks (laboratory and field scale), and modeling of these parameters for code validation.

4. Near-field thermal and mechanical properties: borehole stability as a function of fracture characteristics, rock properties, and thermal environment.

Information that supports these parameters includes work that addresses the following information needs or investigations:

Information need or investigation	Subject
1.4.4	Degradation of containment barriers (Section 8.3.5.9.4)
1.10.3	Reference emplacement configuration (Section 8.3.4.2.3)
1.12	Identification of seals and grouts (Section 8.3.3.2)
8.3.1.2.2	Repository scale hydrologic model
8.3.1.3.4, 8.3.1.3.2	Repository scale mineralogy, petrology, and rock chemistry
8.3.1.3.8	Gaseous radionuclide retardation
8.3.1.15.1	Thermal and mechanical properties of rock

Logic

To ensure that interactions with the emplacement environment do not compromise the function of the waste packages, the composition of water that

may contact the waste packages, the amount of water that may contact the waste packages, and the emplacement hole stability must be established. To provide this information in a form that will allow evaluation of the attributes of the near-field environment, it is necessary to establish within limits the chemical and physical characteristics of the interactive elements in the repository.

Since the water chemistry plays a critical role in determining the performance of the waste package components, goals have been established that define the degree of characterization necessary for water that may contact the waste package.

The attributes that affect water chemistry are

1. Interactive effects caused by the emplacement hole liner and other repository construction materials.

2. Repository thermal loading.

3. Emplacement hole configuration.

4. Radiation dose rate.

5. Near-field hydrologic properties.

6. Mineralogy of the near-field rock.

The planned analyses, evaluations, and activities described in the following section will establish the effects of these attributes. In addition, these activities will establish the credible range of values for individual parameters that relate to water quality, water quantity, and borehole stability. The individual parameters are those discussed in Sections 8.3.4.2.4.1 through 8.3.4.2.4.4, and those parameters that relate to water quality and water quantity in Sections 8.3.5.9 and 8.3.5.10. Once evaluated, the parameters will be used to develop a quantitative model of the anticipated waste package environment. The model of the anticipated environment will consider coupled effects and will explicitly determine the sensitivity of the model to uncertainties in each parameter. In developing the model for the anticipated environment, a range of approaches for evaluating coupled processes will be considered and the relative merits of each method will be documented.

Alternative models and scenarios that consider unanticipated events will also be developed for those scenarios that are credible. These alternative models and scenarios will be based on the degree to which variation is expected in individual parameters. The alternative models and scenarios will be used to evaluate containment and gradual release performance issues, as described in Sections 8.3.5.9 and 8.3.5.10.

The attributes described above will influence the thermal history of the repository and will establish the extent of chemical interaction between water present in the waste package environment, the repository host rock, and the waste package materials.

The stability of the emplacement boreholes must be investigated because instability of the borehole could result in unacceptable loading of the package by rock. Borehole stability considerations will be examined through activities and tests of the near-field waste package environment in the candidate repository horizon as part of the Project exploratory shaft in situ testing program.

Waste package environment field tests will be configured to provide site-specific data on near-field hydrologic, thermal, mechanical, and chemical phenomena during an accelerated thermal cycle in the rock mass. Although near-field hydrologic phenomena (movement of water in rock pores or fractures) are of primary interest, thermal and mechanical phenomena are also of interest because of their roles in driving or influencing water migration. Chemical phenomena are important because of their potential influence on hydrologic behavior and because of possible effects on components of the engineered barrier system.

Engineered barriers (including borehole liners) and shaft and borehole seals may influence water composition. The character of seals is discussed in Section 8.3.3. Borehole liners and the effects of other materials are addressed in the following section describing Study 1.10.4.1.

8.3.4.2.4.1 Study 1.10.4.1: Characterize chemical and mineralogical changes in the postemplacement environment

The objective of this study is to establish, to the degree required in Performance Issues 1.4 and 1.5 (Sections 8.3.5.9 and 8.3.5.10), the compositional features of water that may contact the waste packages. To accomplish this objective, it is necessary to determine the effects of chemical reactions on the rock-water system of the repository horizon over a range of temperatures and chemical conditions that bound the postclosure waste package environment. Seven activities are planned to collect the data needed for this study.

8.3.4.2.4.1.1 Activity 1.10.4.1.1: Rock-water interactions at elevated temperatures

Objectives

The objective of this activity is to establish the identity and abundance of reaction products that form during hydrothermal interaction of tuff and reference ground water at elevated temperatures.

Parameters

The parameters of this activity include

1. Temperature.
2. Compositions of reactant and solid phases.
3. Fluid composition as a function of time.

4. Reactant surface area.
5. Modal abundance of solid reactants and products.

Description

The anticipated conditions for the waste package environment include an unsaturated rock system. Reaction rates in such an environment are exceptionally low, and the identity of solid reaction products can be difficult to establish. Therefore, tests to characterize in detail the chemical behavior of a water-saturated liquid and vapor environment will be conducted to bound the nature of hydrothermal reaction products, to provide a conceptual framework to aid interpretation of work carried out in an unsaturated environment, and to establish reaction characteristics for the unanticipated condition of a saturated environment. Tests and experiments similar to those described in Section 7.4.1.7 will be conducted at elevated temperatures (90 to 250°C) that will span the range of anticipated thermal conditions of the waste package host rock. Studies at lower temperatures are not being considered because reaction rates in geologic materials at such temperatures are too slow to provide meaningful results within the available time. Although it is not expected that significant quantities of liquid water will exist in the waste package environment when the temperature exceeds approximately 100°C, high-temperature (>100°C) studies will be conducted to characterize the stability fields of phases important in the low-temperature tests. These data will also provide information on reaction kinetics and rate laws appropriate for the phases involved in lower-temperature reactions and will provide means to extrapolate reaction behavior to lower temperatures.

The studies will examine the nature of reaction products in hydrothermal systems containing Topopah Spring tuff and water that is believed to be representative of vadose water in the repository horizon. Comparison of the reaction products with mineral assemblages and mineral compositions in natural systems will allow evaluation of the applicability of the laboratory results to the repository environment.

Sample material for the tests will be obtained from the appropriate geologic horizon. Wafers of the sample will be cut, polished on one side, examined using a scanning electron microscope (SEM) and electron microprobe, and mounted in the reaction vessel of a Dickson-type rocking autoclave or other appropriate reaction vessel. If studies of the solid reaction products are not to be undertaken, crushed tuff, rather than a rock wafer, will be placed in the reaction vessel. Sufficient fluid, of the appropriate composition, will be added to the reaction vessel to last the duration of the test. The reaction vessel will then be taken to the temperature and pressure considered for the test. The reaction vessel will be kept at these conditions for the time necessary for the rock-water system to approach equilibrium. Fluid will be periodically extracted from the reaction vessel for chemical analysis. At completion of the test, the rock wafer will be removed and examined for reaction products in the SEM and the electron microprobe. If crushed rock is used in the test, instead of a rock wafer, the material will be examined by x-ray diffraction and SEM.

Methods and technical procedures

The methods and technical procedures for Activity 1.10.4.1.1 are given in the following table.

Method	Technical procedure		
	Number	Title	Date
Determination of rock-water interactions	033-NNWSI-P 8.1	Preparation of crushed rock samples	TBD[a]
	033-NNWSI-P 8.2	Sample cataloging procedures	TBD
	033-NNWSI-P 8.3	Procedure for preparing core water samples	TBD
	033-NNWSI-P 8.4	Sample labeling and tracking	TBD
	033-NNWSI-P 11.2	Procedure for carbonate analysis using the OIC model 524D carbon analyzer	TBD
	033-NNWSI-P 11.3	Testing rock-water interaction using a rocking autoclave	22 May 87
	033-NNWSI-P 11.4	X-ray diffraction characterization	TBD
	033-NNWSI-P 11.5	Determination of anions in water by ion chromatography	TBD
	033-NNWSI-P 11.6	ICP-AES analysis for trace elements in solutions	TBD
	033-NNWSI-P 12.2	Calibrating balances	18 Feb 87
	033-NNWSI-P 12.3	Calibrating datalog systems, temperature controllers and digital displays	TBD

Method	Technical procedure Number	Title	Date
Determination of rock-water interactions (continued)	033-NNWSI-P 12.4	Calibrating pressure transducers	TBD
	033-NNWSI-P 12.5	Calibration of thermocouples	TBD
	033-NNWSI-P 12.6	Measurement of the pH of aqueous solutions with the glass electrode	TBD
	033-NNWSI-P 13.1	Collection, storage, and distribution of J-13 water	21 Apr 87

[a]TBD = to be determined.

8.3.4.2.4.1.2 Activity 1.10.4.1.2: Effect of grout, concrete, and other repository materials on water composition

Objectives

The objective of this activity is to test the rock-water interaction in the presence of concretes, grouts, and other repository materials (Section 8.3.3) when the identity of the other materials is established. The objective of these tests is to determine if the proposed material satisfies the requirements specified in the performance allocation for this issue relating to effects of engineered barriers, shafts, and seals on water chemistry. The parameters and laboratory methods appropriate to this activity will be established when the other materials are identified.

8.3.4.2.4.1.3 Activity 1.10.4.1.3: Composition of vadose water from the waste package environment

Objectives

The objective of this activity is to characterize the composition of vadose water in the unsaturated, preemplacement waste package environment.

Parameters

The parameter of this activity is the chemical composition of vadose water in tuff of the repository horizon.

Description

A test will be conducted to extract pore water from representative devitrified, welded tuff. The extracted fluid will be analyzed using standard inductively coupled plasma and ion chromatography procedures. This test will be designed to determine the method that produces the most representative fluid composition for the environment. Analyses of the collected fluid will be compared with theoretical models of rock-water interaction and known characteristics of vadose fluids in equilibrium with minerals present in the rock, to evaluate whether a particular extraction technique produces uncontaminated fluid. Once an extraction method is selected, vadose water will be extracted from core uncontaminated with drilling fluids and from exploratory shaft material collected at the repository horizon. The need for this activity is discussed in Sections 7.4.1.1, 7.4.1.3, and 7.4.1.7.

This activity will establish the variability of vadose water composition within the repository horizon. This information will define the bounds to be expected on vadose water composition in the pre-emplacement waste package environment. This activity complements the work of the U.S Geological Survey, which will characterize the regional and stratigraphic variability of pore water chemistry, as described in Section 8.3.1.2.2.8.2.

Design of these tests is in progress.

8.3.4.2.4.1.4 Activity 1.10.4.1.4: Dissolution of phases in the waste package environment

Objectives

The objective of this activity is to determine the dissolution kinetics of the phases present in the waste package environment.

Parameters

The parameters of this activity include

1. Temperature.
2. Solution pH.
3. Mineral composition and structural state.

Description

In rock-water interaction studies, dissolution of reactant phases and the concomitant precipitation of product phases control the rates of chemical reaction. To understand the kinetics of mineral precipitation and to interpret the evolution of the fluid ccmposition in hydrothermal tests, knowledge of the dissolution kinetics of the phases present in the host rock is

required. Data on the kinetics of dissolution of phases of interest are sparse and must therefore be obtained through laboratory studies, as discussed in Section 7.4.1.7.

Dissolution studies will be conducted over a range of temperatures and fluid pH to determine the sensitivity of the dissolution kinetics to temperature and variation in the chemistry of the environment. Phases used in the dissolution studies will include the principal constituents of the devitrified, welded tuff and the common secondary phases associated with rock-water interaction as identified in hydrothermal tests and experiments. Tests will also be conducted to determine the degree to which vapor-phase transport and dissolution will occur under conditions anticipated in the waste package environment.

The mineral of interest will be crushed to a specific size range and washed thoroughly to remove adhering fine particles. Brunauer-Emmett-Teller surface area measurements will be conducted to determine the surface area of the material. For tests at temperatures less than 95°C, the sample will then be weighed and placed in small flow-through dissolution cells. Each cell will be attached to a fluid stream of known pH and flow rate. The cell will then be placed in a controlled-temperature environment for specified periods of time. The fluid that passes through the cell will be collected and periodically analyzed for the elements of interest. Statistical analysis of the results, using transition state theory, will be used to model the kinetics of the dissolution process. Laboratory protocol for dissolution studies at temperatures in excess of 100°C is still in development.

8.3.4.2.4.1.5 Activity 1.10.4.1.5: Effects of radiation on water chemistry

Objectives

The objective of this activity is to determine the composition of water in the presence of a radiation field under postemplacement conditions.

Parameters

The parameters of this activity include

1. Temperature.
2. Radiation dose rate.
3. Degree of water saturation.
4. Nature of solid materials present in addition to tuff.

Description

In water-saturated air, the abundance and composition of the radiolysis products that develop in a radiation field are a sensitive function of the temperature and the radiation dose rate. In addition, chemical reactions may take place between the radiolysis products and any other material present in the system. For example, it remains unclear which chemical reactions occur in the presence of iron and manganese oxides that may influence colloid development, nitrite-to-nitrate ratio, and the relative abundances of other

nitrogen-bearing compounds. This activity will determine the chemical composition of the water and air that develops at different radiation dose rates, over a range of temperatures, and in the presence of materials expected in the waste package environment.

Reaction vessels containing tuff, waste package container metal, and reference ground water are placed in a gamma radiation field. The reaction vessels are then subjected to a specified radiation dose rate, at a specific temperature, for an extended period of time. Samples of the solution that develop during the course of the exposure are then chemically analyzed. A matrix of tests over a range of temperatures and radiation dose rates will allow identification of the significance of individual reaction parameters.

The results of these tests are used as input to guide modeling of rock-water interaction in the presence of a radiation field. The rates of dissolution and precipitation of radiolysis products and the identification of solid products formed through interaction of tuff with irradiated fluid provide constraints on the modeling. The geochemical modeling code EQ3/6 (discussed in Section 7.4.4) will be used to extend to long time periods (and to conditions not represented in the matrix of tests) the chemical behavior of the tuff-water system in the presence of radiation and other materials.

8.3.4.2.4.1.6 Activity 1.10.4.1.6: Effects of container and borehole liner corrosion products on water chemistry

Objectives

The objective of this activity is to determine the effect of corrosion products on the composition of water in the package environment.

Parameters

The parameters of this activity include

1. Temperature.
2. Composition and mineralogy of corrosion products.
3. Degree of water saturation.

Description

The effect of corrosion products on the waste package environment and water chemistry will be established through a matrix of long-term tests in which tuff, reference ground water, and metal are commingled at elevated temperatures. The metals used in the test will be partially submerged, if liquid water is present, and will be exposed to the gaseous atmosphere present in the test vessel. Periodic sampling of the fluid phase will be conducted to determine the chemical evolution of the fluid through time. At the conclusion of the tests and experiments, the metal samples and the tuff will be examined by using SEM/electron dispersive spectroscopy to determine the abundance and nature of reactions and corrosion products, their modes of occurrence, and their composition.

8.3.4.2.4.1.7 Activity 1.10.4.1.7: Numerical analysis and modeling of rock-water interaction

Objectives

The objective of this activity is to examine effects and processes in natural systems for time periods and chemical conditions not duplicated by laboratory studies.

Parameters

The parameters of this activity include

1. Temperature.
2. Mineral assemblage.
3. Mineral species surface areas.
4. Reaction times.
5. Fluid composition.

Description

Laboratory studies are incapable of examining the effects of all the possible values of parameters significant for the system under consideration. Nor can laboratory studies be used to extend directly to periods of many years the behavior of natural systems studied in the laboratory over periods of months. However, the use of numerical studies, in conjunction with judiciously selected tests, can provide the capability to establish the behavior of natural systems for conditions not duplicated by laboratory tests.

The numerical analysis and modeling will be used to predict the results of previously completed tests for characterizing the reaction process. For any geochemical test under consideration, the computer code EQ3/6 (discussed in Section 7.4.4) will use as input the mineralogy of the reactant rock material, the surface area of the reactant solid phases, and the composition of the water. The code then computes (for the temperature of the test and the reaction interval step chosen) the composition of the fluid at each reaction step, the degree of saturation of appropriate mineral phases, and the quantity of minerals precipitated from solution. This approach also allows characterization of reaction processes under conditions not duplicated by the laboratory studies and can be used to extrapolate the results of laboratory studies to repository time and distance scales. The uncertainties in the thermodynamic and kinetics data used in the calculations will be evaluated.

Methods and technical procedures

The methods and technical procedures for Activity 1.10.4.1.7 are given in the following table.

Method	Technical procedure Number	Title	Date
Numerical analyses and modeling of rock-water interaction	033-NNWSI-P 8.1	Preparation of crushed rock samples	TBD[a]
	033-NNWSI-P 8.2	Sample cataloging procedures	TBD
	033-NNWSI-P 8.3	Procedure for preparing core water samples	TBD
	033-NNWSI-P 8.4	Sample labeling and tracking	TBD
	033-NNWSI-P 11.2	Procedure for carbonate analysis using the OIC model 524D carbon analyzer	TBD
	033-NNWSI-P 11.3	Testing rock-water interaction using a rocking autoclave	22 May 87
	033-NNWSI-P 11.4	X-ray diffraction characterization	TBD
	033-NNWSI-P 11.5	Determination of anions in water by ion chromography	TBD
	033-NNWSI-P 11.6	ICP-AES analysis for trace elements in solutions	TBD
	033-NNWSI-P 12.2	Calibrating balances	18 Feb 87
	033-NNWSI-P 12.3	Calibrating datalog systems, temperature controllers, and digital displays	TBD
	033-NNWSI-P 12.4	Calibrating pressure transducers	TBD

Method	Technical procedure		
	Number	Title	Date
Numerical analyses and modeling of rock-water interaction (continued)	033-NNWSI-P 12.5	Calibration of thermocouples	TBD
	033-NNWSI-P 12.6	Measurement of the pH of aqueous solutions with the glass	TBD
	033-NNWSI-P 13.1	Collection, storage, and distribution of J-13 water	21 Apr 87

[a]TBD = to be determined.

8.3.4.2.4.2 Study 1.10.4.2: Hydrologic properties of waste package environment

The objectives of this study are to establish the hydrologic properties of the near-field repository rock and the effect of thermal perturbation on these hydrologic properties, over the range of anticipated postemplacement conditions. This study will establish the conditions under which fracture flow will predominate over matrix flow and will determine the relative hydrologic importance of gas versus liquid-phase transport under isothermal and polythermal conditions appropriate for the waste package environment. This study will also determine the degree to which thermal effects will modify the ambient hydrologic properties. Isothermal components will provide input for simulation of conditions during the controlled release period and provide partial validation for nonisothermal codes.

Waste package performance assessment calculations will require boundary conditions representing the host rock environment. A hydrothermal flow and transport model will be developed to simulate moisture and contaminant movement in the matrix and fractures of the host rock. The flow model will be composed of the conservation equations for fluid mass, momentum, and energy in a fractured porous medium. Thermodynamic relationships will be included for the water-steam phase changes. Constitutive relationships will include the equation of state for vapor and air components. In addition to flow calculations, this model will also provide the temperature of the surrounding rock mass and the state of saturation for all fluid phases as functions of space and time.

The transport model will use the pore velocities calculated by the flow model and then solve the transport equation for each radionuclide. Transport processes will include advection, molecular diffusion, and dispersion. Radionuclide decay, sorption, and solubility limits also influence the concentrations of radionuclides, and these processes will be included. This model will provide the concentrations of ground-water chemical species of interest to the representation of the waste package environment. In addition, the concentrations of released radionuclide species, both in the ground water and sorbed to the rock matrix, may be determined as a function of time and space.

The flow and transport models will be used to establish the quantity of water that may contact waste containers. Consideration will be given to the range of flow pathways identified in field and laboratory tests and to anticipated and unanticipated hydrologic conditions defined by activities that establish the Yucca Mountain site hydrology (Section 8.3.1.2). These flow and transport models will provide the basis for establishing the extent to which near-field hydrologic properties will contribute to satisfying water quantity performance goals set in Issues 1.4 and 1.5.

Conclusions regarding fluid transport behavior in a thermally perturbed environment will be verified through field studies in the exploratory shaft, as described in Sections 7.4.1.1 and 7.4.1.5, and through work under Characterization Program 8.3.1.2. Study 1.10.4.2 consists of three laboratory and modeling activities.

8.3.4.2.4.2.1 Activity 1.10.4.2.1: Single-phase fluid system properties

Objectives

The objectives of this activity are

1. To establish the single-fluid-phase hydrologic properties of fractured and unfractured tuff under isothermal conditions.

2. To establish the single-fluid-phase hydrologic properties of fractured and unfractured tuff in a thermal gradient.

Parameters

The parameters of this activity include

1. Temperature.
2. Relative permeability.
3. Degree of saturation.
4. Nature of the fluid phase.
5. Number of rehydration-dehydration cycles.
6. Resistivity.
7. Magnitude of thermal gradient.

Description

Dehydration-rehydration processes may modify the hydrologic properties of the near-field rock through precipitation-dissolution effects or through induced changes in fracture surface characteristics. The pattern of fluid flow that may develop as a result of heat transfer and mass transport may take several forms, including convective flow and "heat pipe" geometries. Such processes have the potential of developing regions where fluids may condense or areas where transported solutes may concentrate. These processes could change the chemistry, mineralogy, and hydrology of the waste package environment and therefore must be characterized to satisfy Information Need 1.10.4 (Section 8.3.4.2.4).

Fractured and unfractured samples will be used to examine the fluid flow properties of single-phase (gas or liquid) systems. Tests will be run in isothermal conditions and in thermal gradients to determine the fluid flow behavior in different thermal regimes. These tests will be run under pressure conditions that simulate loading at the repository level. These tests will address data needs described in Section 7.4.1.6. The characteristics of fluid flow in these different environments will be documented by using computed impedance tomography. Computed impedance tomography is an imaging technique that uses electrical resistivity measurements taken sequentially around a circumference of a rock core to obtain variations in resistivity within the core. The resistivity measurements may be converted to degree of liquid saturation, thereby providing a two-dimensional map of liquid saturation on a plane normal to the cylinder axis. Modification of fracture surfaces and pores will be documented.

Methods and technical procedures

The methods and technical procedures for Activity 1.10.4.2.1 are given in the following table.

Method	Technical procedure		
	Number	Title	Date
Determination of single-phase fluid system properties	033-NNWSI-P 8.2	Sample cataloging procedures	TBD[a]
	033-NNWSI-P 8.4	Sample labeling and tracking	TBD
	033-NNWSI-P 11.5	Determination of anions in water by ion chromography	TBD

Method	Technical procedure Number	Title	Date
Determination of single-phase fluid system properties (continued)	033-NNWSI-P P 11.6	ICP-AES analysis for trace elements in solutions	TBD
	033-NNWSI-P 12.4	Calibrating pressure transducers	TBD
	033-NNWSI-P 12.5	Calibration of thermocouples	TBD
	033-NNWSI-P 13.1	Collection, storage, and distribution of J-13 water	21 Apr 87

[a]TBD = to be determined..

8.3.4.2.4.2.2 Activity 1.10.4.2.2: Two-phase fluid system properties

Objectives

The objectives of this activity are

1. To establish the two-phase hydrologic properties of tuff under isothermal conditions.

2. To establish the two-phase hydrologic properties of tuff in a thermal gradient.

Parameters

The parameters of this activity are

1. Temperature.
2. Relative permeability.
3. Degree of saturation.
4. Gas-to-liquid ratio.
5. Resistivity.
6. Number of rehydration-dehydration cycles.
7. Magnitude of temperature gradient.

Description

Tests in the two-phase system will be designed to establish the effects of a two-phase fluid on the hydrologic properties of the tuff, to allow comparison with results from the single-phase fluid tests. The single-phase and two-phase studies will characterize the tuff-fluid system over the range of conditions anticipated in the postemplacement waste package environment.

The laboratory protocol for the two-phase activities is similar to that for the single-phase activities, with the exception that the ratio of liquid to gas is an additional parameter that will be controlled in the tests. These tests are performed in a pressure vessel under simulated in situ conditions. The work described here addresses needs described in Sections 7.4.1.1, 7.4.1.5, and 7.4.1.6.

8.3.4.2.4.2.3 Activity 1.10.4.2.3: Numerical analysis of flow and transport in laboratory systems

Objectives

The objective of this activity is to use laboratory-scale tests for initial development and validation of the flow and transport code.

Parameters

The parameters of this activity are

1. Temperature.
2. Distribution of liquid-phase saturation.
3. Permeability.
4. Hydraulic conductivity.

Description

The hydrothermal flow model will require validation over a range of conditions sufficient to cover those required in the use of the model. Validation requires that model predictions be compared with controlled tests, from both laboratory and in situ investigations. The laboratory measurements of two-phase flow in rock cores conducted under Study 1.10.4.2 (Section 8.3.4.2.4.2) will partially satisfy the validation needs of the hydrothermal flow model. The primary variables to be used for validation will be the core temperature and saturation distributions. Other properties required will include the thermal properties of the core material. The parameters subject to validation will be the permeability and the expressions used to represent matric potential and relative conductivity as functions of saturation. By using these test results, the model can be tested on one- and two-dimensional systems under controlled but varying thermal and flow conditions. This vali-dation will concentrate on simulation of flow in a small core and, therefore, will provide a limited validation before testing on a scale representative of the waste package environment.

8.3.4.2.4.3 Study 1.10.4.3: Mechanical attributes of the waste package environment

The objectives of this study are to establish the mechanical attributes of the waste package environment host rock. The need for this information is discussed in Section 7.4.1.1 and 7.4.1.2. The mechanical studies will examine the mechanical response of the near-field rock to the engineering and thermal regimes resulting from development of the repository and emplacement of the waste packages. The mechanical properties determine the extent to which borehole wall failure can be expected to load the waste package containers.

8.3.4.2.4.3.1 Activity 1.10.4.3.1: Waste package environment stress field analysis

Objectives

The objective of this activity is to estimate the time-dependent stress field and displacements of the rock in the waste package environment.

Parameters

The parameters of this activity are

1. Emplacement configuration.
2. Repository layout.
3. Temperature fields.
4. Mechanical properties of rock in repository horizon (TSw2), including for example, Young's modulus, Poisson's ration, deformation modulus, coefficient of thermal expansion, and strength-related properties.
5. Fracture (joint) characteristics of rock in repository horizon (TSw2), including for example, shear and normal stiffness, orientation, and frequency and degree of persistence.

Description

The extent to which waste containers can be loaded by rock-induced stresses will be evaluated. One of the potential mechanisms for such loading is slip of discrete blocks of rock along preexisting fractures. Field data describing the attributes of the fractures will be used with repository design information, predicted temperatures, and mechanical properties of the host rock to predict the possible extent and modes of block failure for the range of conditions anticipated in the repository horizon. The integration of the field data with the design specifications for the emplacement geometry, container spacing, and the liner will be accomplished by using computer modeling and, if necessary, model tests.

8.3.4.2.4.4 Study 1.10.4.1: Engineered barrier system field tests

The laboratory tests described in Activities 1.10.4.1.1 through 1.10.4.1.7 (Sections 8.3.4.2.4.1.1 through 8.3.4.2.4.1.7) and 1.10.4.2.1 through 1.10.4.2.3 (Sections 8.3.4.2.4.2.1 through 8.3.4.2.4.2.3) require validation through in situ field tests in the repository horizon to establish the applicability of the laboratory studies to the repository block. These tests will be conducted in the exploratory shaft facilities at the repository horizon. The activities listed below indicate the objectives of the work to be completed and the parameters to be determined. Detailed descriptions of the activities will be available when the indicated test plans are completed. The work described in these activities addresses needs described in Sections 7.4.1.1., 7.4.1.5, and 7.4.1.6. The three activities in this study are described in the following sections.

Before initiation of the in situ tests that support this study, prototype tests to develop and validate the test procedures and protocols are planned. These prototype tests will be conducted in the G-tunnel test facility located in a similar hydrogeologic setting in Rainier Mesa at the Nevada Test Site. The prototype tests are designed to simulate the test conditions and evaluate the installation procedures and performance characteristics of the instrumentation planned for the in situ tests to be deployed in the Yucca Mountain exploratory shaft facility.

8.3.4.2.4.4.1 Activity 1.10.4.4.1: Repository horizon near-field hydrologic properties

Objectives

The objective of this activity is to determine the in situ hydrologic properties of rock in the repository horizon under thermally perturbed conditions.

Parameters

The parameters of this activity are

1. Degree of liquid water saturation.
2. Relative permeability.
3. Matric potential.
4. Fluid flow pathways.
5. Fluid flow rates.
6. Fracture characteristics.
7. Thermal loading.
8. Mechanical and thermal properties of the rock.

Description

Geotechnical and hydrologic instrumentation will be deployed to monitor selected near-field environmental parameters in situ. These measurements will allow characterization of the parameters just enumerated. In addition, laboratory-scale hydrologic studies will be completed, with computed

impedance tomography techniques, on samples obtained from the repository horizon. Comparison of the data obtained from the field studies and laboratory studies with those obtained from earlier laboratory tests will extend the applicability of the laboratory tests to the in situ waste package environment.

8.3.4.2.4.4.2 Activity 1.10.4.4.2: Repository horizon rock-water interaction

Objectives

The objective of this activity is to determine the effect on water chemistry of thermal perturbation of the near-field environment.

Parameters

The parameters of this activity are

1. Temperature.
2. Temperature gradient.
3. Water chemistry.
4. Mineralogical changes.

Description

Geotechnical and hydrologic instrumentation will be deployed to monitor selected near-field environmental parameters in situ. In addition, laboratory tests and analyses will be conducted as described in the test plan. These measurements will provide the background for characterization of the parameters enumerated above. Once established, comparison of these parameters with those obtained from previous laboratory tests will extend the applicability of the laboratory tests to the in situ waste package environment. Pretest and posttest rock and water samples will be analyzed for changes in mineralogy and chemistry. These activities will provide data for integration with laboratory-scale measurements. These activities will address needs described in Sections 7.4.1.1, 7.4.1.5, and 7.4.1.7.

Methods and technical procedures

The methods and technical procedures for Activity 1.10.4.4.2 are given in the following table.

Method	Technical procedure		
	Number	Title	Date
Determination of near-field hydrologic properties	033-NNWSI-P 11.11	Borescope surveys to map fractures intercepting boreholes	7 Jan 88
	033-NNWSI-P 11.12	Neutron and gamma (density) logging in welded tuff	16 Dec 87
	TBD[a]	Installation and operation of the electromagnetic measurement system	TBD
	TBD	Measurement of suction potential via relative humidity in unsaturated rock	TBD
	TBD	Temperature measurements	TBD
	TBD	Air pressure measurements	TBD
	TBD	Installation and operation of the data acquisition system	TBD
	TBD	Air permeability measurements	TBD
	TBD	Grouting of measurement boreholes	TBD
	TBD	Installation and operation of heater assembly and moisture collection system	TBD

Method	Technical procedure		
	Number	Title	Date
Determination of near-field hydrologic properties (continued)	033-NNWSI-P 11.13	Borehole television humidity measure- surveys to map fractures along horizontal and sub-horizontal boreholes	19 Feb 88
	TBD	Microwave resonator ments	TBD
	033-NNWSI-P 11.10	Prototype engineered barrier design testing - horizontal emplacement (Rev. 1)	7 Jun 88
Determination of near-field rock-water interaction	033-NNWSI-P 11.11	Borescope surveys to map fractures intercepting boreholes	7 Jan 88
	033-NNWSI-P 11.12	Neutron and gamma (density) logging in welded tuff	16 Dec 87
	TBD	Installation and operation of the electromagnetic measurement system	TBD
	TBD	Measurement of suction potential via relative humidity in unsaturated rock	TBD
	TBD	Temperature measurements	TBD
	TBD	Air pressure measurements	TBD
	TBD	Installation and operation of the data acquisition system	TBD
	TBD	Air permeability measurements	TBD

Method	Technical procedure Number	Title	Date
Determination of near-field rock water interaction (continued)	TBD	Grouting of measurement boreholes	TBD
	TBD	Installation and operation of heater assembly and moisture collection system	TBD
	033-NNWSI-P 11.13	Borehole television surveys to map fractures along horizontal and subhorizontal boreholes	19 Feb 88
	TBD	Microwave resonator humidity measurements	TBD
	033-NNWSI-P 11.10	Prototype engineered barrier design testing - horizontal emplacement (Rev. 1)	7 Jun 88

[a]TBD = to be determined.

8.3.4.2.4.4.3 Activity 1.10.4.4.3: Numerical analysis of fluid flow and transport in the repository horizon near-field environment

Objectives

The objective of this activity is to validate and calibrate fluid flow, temperature, and transport models by using waste-package-scale field studies.

Parameters

The parameters of this activity are

1. Fracture attributes.
2. Temperature.
3. Degree and distribution of saturation.
4. Time.
5. Sorption.
6. Water composition.

7. Emplacement configuration.
8. Repository layout.
9. Waste package configurations.
10. Waste package heat generation characteristics.

Description

The flow and transport model will require calibration on a scale representative of the waste package environment. Testing on this scale, as described in Activity 1.10.4.4.1 (Section 8.3.4.2.4.4.1), will allow the influence of fractures on the flow of liquid water and steam to be observed. Tests at the repository horizon in the exploratory shaft will provide the ability to test the model at a scale approximating the waste package emplacement conditions. To perform this calibration and validation, temperature and degree of liquid saturation of the rock mass and concentration of tracers and sorbed substances must be observed under different simulated emplacement conditions. Other measurements such as pressure of the gas phase in matrix and fractures would be useful but may not be practical. The primary benefit of these tests will be to test the effect of fractures on moisture movement in the rock mass.

The transport capability of the flow and transport model will be used to describe the movement of radionuclides and naturally occurring aqueous chemical constituents in the near field; that is, the first several meters of host rock surrounding an emplacement hole. These calculations will be used respectively in tracking releases and assigning boundary conditions for performance calculations. Therefore, the transport portion of the model must also be validated.

The thermal studies will address the history, magnitude, and nature of the thermal perturbation associated with waste packages in the emplacement configurations under consideration. This history establishes the thermal conditions under which rock-water interaction may occur. The magnitude of the temperature field that develops around a waste package is a complex function that depends on how the packages are spaced within the repository and how much heat the packages dissipate through time. Additional variables include the relative diameters of the borehole and the container and whether the borehole has been lined.

Modeling of the thermal history of the near-field environment will be conducted by using a test matrix consisting of the variables that influence the temperature field of the waste package environment. A computer code for hydrothermal flow in unsaturated rock will be used to evaluate the effect of each variable over the range of conditions anticipated for the repository. The results will be used to establish the thermal behavior of the near-field environment.

In situ test will be conducted to monitor the movement of sorbing and nonsorbing species. These measurements will include the concentration of species in the pore water as a function of time and space and the concentration of species sorbed onto the tuff matrix at specified times and locations. Calibration of the transport routines will consist of deriving dispersivities and effective diffusion coefficients for the test location. Since measurements will be used to calibrate and validate the transport

routines of the hydrothermal model, it will be necessary to design the tests so that several data sets will be available for a given set of geologic parameters.

Methods and technical procedures

The methods and technical procedures for Activity 1.10.4.4.3 are given in the following table.

Method	Technical procedure		
	Number	Title	Date
Calibration and validation of fluid flow and transport models in the near-field environment	033-NNWSI-P 11.11	Borescope surveys to map fractures intercepting Boreholes	7 Jan 88
	033-NNWSI-P 11.12	Neutron and gamma (density) logging in welded tuff	16 Dec 87
	TBD[a]	Installation and operation of the electromagnetic measurement system	TBD
	TBD	Measurement of suction potential via relative humidity in unsaturated rock	TBD
	TBD	Temperature measurements	TBD
	TBD	Air pressure measurements	TBD
	TBD	Installation and operation of the data acquisition system	TBD
	TBD	Air permeability measurements	TBD
	TBD	Grouting of measurement boreholes	TBD

Method	Technical procedure Number	Title	Date
Calibration and validation of fluid flow and transport models in the near-field environment (continued)	TBD	Installation and operation of heater assembly and moisture collection system	TBD
	033-NNWSI-P 11.13	Borehole television surveys to map fractures along horizontal and sub-horizontal boreholes	19 Feb 88
	TBD	Microwave resonator humidity measurements	TBD
	033-NNWSI-P 11.10	Prototype engineered barrier design testing - horizontal emplacement (Rev. 1)	7 Jun 88

[a]TBD = to be determined.

8.3.4.2.4.5 Application of results

The information derived from activities described above will be used in addressing the following information needs and investigations:

Information need or investigation	Subject
1.4.2	Material properties of the containment barrier (Section 8.3.5.9.2)
1.4.3	Scenarios and models needed to predict the time to loss of containment and the ensuing degradation of the containment barrier (Section 8.3.5.9.3)
1.4.4	Containment barrier degradation (Section 8.3.5.9.4)

1.5.2	Material properties of the waste form (Section 8.3.5.10.2)
1.5.3	Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system (Section 8.3.5.10.3)
1.5.4	Release rates of radionuclides from the engineered barrier system for anticipated and unanticipated events (Section 8.3.5.10.4)
1.10.1	Design information needed (consideration of waste package-environment interactions) (Section 8.3.4.2.1)
1.10.3	Waste package emplacement configuration (Section 8.3.4.2.3)
1.10.4	Postclosure near-field environment (Section 8.3.4.2.4)
1.11	Configuration of the underground facility (Section 8.3.2.2)
1.12.2	Seal materials (Section 8.3.3.2.2)

The activities described previously will define the chemical and physical attributes of the waste package environment, which is information required to satisfy the listed information needs.

8.3.4.2.5 Schedule for postclosure waste package characteristics

Issue 1.10 (postclosure waste package characteristics) includes 4 information needs which contain 4 studies all of which are in Information Need 1.10.4 (near-field environment). The schedule information for the information needs and studies of 1.10.4 is summarized in Figure 8.3.4.2-3. This figure includes the information need or study number and a brief description, as well as major events associated with each information need or study. A major event, for purposes of these schedules, may represent the initiation or completion of an activity, completion or submittal of a report to the DOE, an important data feed, or a decision point. Solid lines on the schedule represent activity durations and dashed lines show interfaces among studies or information needs as well as data transferred into or out of this design issue. The events shown on the schedule and their planned dates of completion are provided in Table 8.3.4.2-5.

The schedules, in combination with information provided in the logic diagrams for this issue (Figures 8.3.4.2-1 and -2), are intended to provide the reader with a basic understanding of the relationships between major elements of the site, performance, and design programs. The information provided in Table 8.3.4.2-5 and Figure 8.3.4.2-3, however, should be viewed as a snapshot in time.

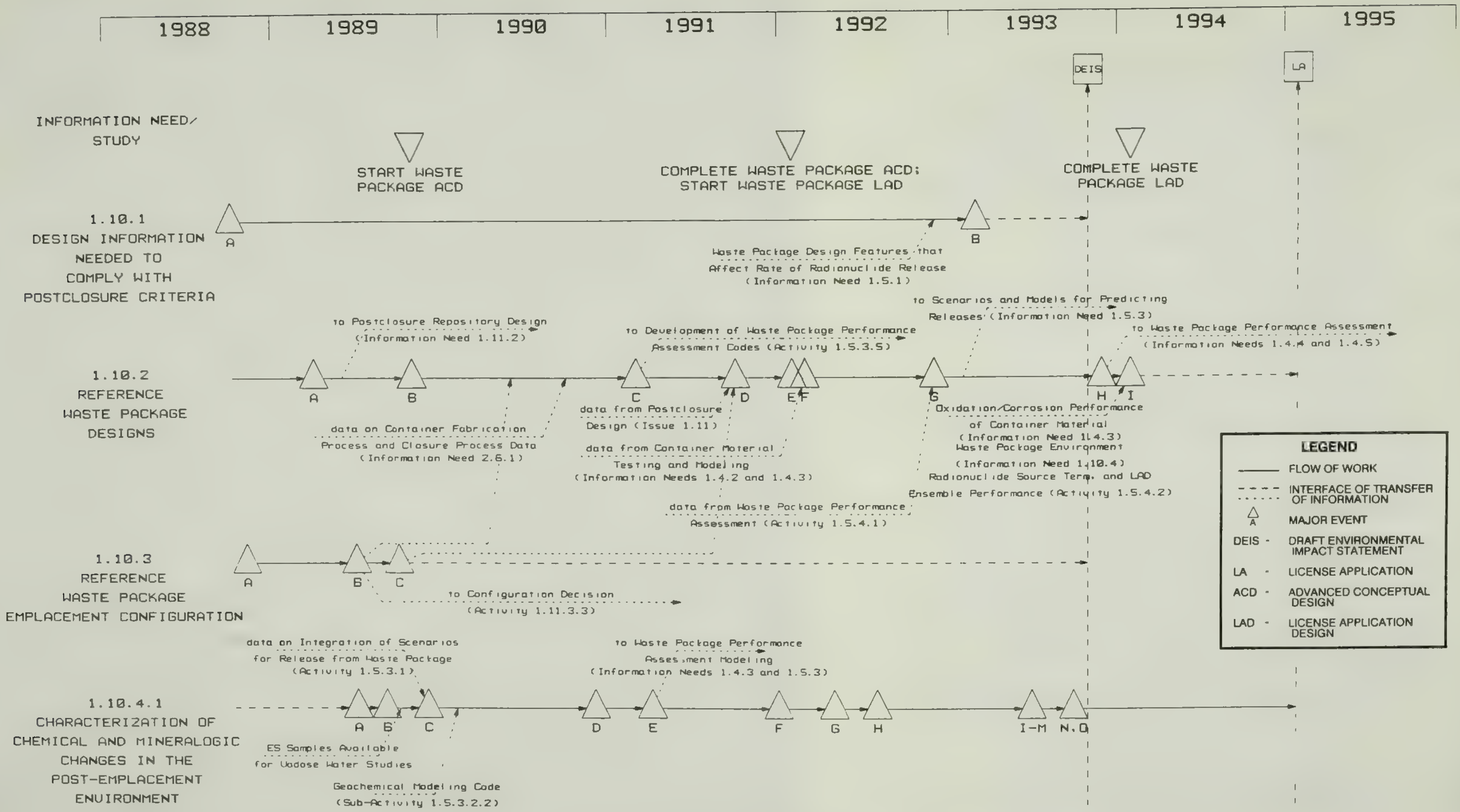


Figure 8.3.4.2-3. Schedule information for the information needs and studies for Issue 1.10 (waste package characteristics–postclosure) See Table 8.3.4.2-5 for description of major events This network is consistent with the Draft Mission Plan Amendment (DOE, 1988a) schedule Revisions will be published in semiannual site characterization progress reports as new information becomes available (page 1 of 2)

DECEMBER 1988

1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995

DEIS

LA

INFORMATION NEED/ STUDY (CONTINUED)

START WASTE PACKAGE ACD

COMPLETE WASTE PACKAGE ACD; START WASTE PACKAGE LAD

COMPLETE WASTE PACKAGE LAD

1.10.4.2 DETERMINATION OF HYDROLOGIC PROPERTIES OF THE WASTE PACKAGE ENVIRONMENT

A B C D E F G

to Total System Performance (Issue 1.1)

to Reference Waste Package Design (Information Need 1.10.2)

1.10.4.3 DETERMINATION OF THERMAL AND MECHANICAL ATTRIBUTES OF THE WASTE PACKAGE ENVIRONMENT

A B C D

1.10.4.4 ENGINEERED BARRIER SYSTEM FIELD TESTS

A B C D E

to Total System Performance (Issue 1.1 and Information Need 1.5.5)

CONFIRMATORY TEST PHASE

Figure 8.3.4.2-3. Schedule information for the information needs and studies for Issue 1.10 (waste package characteristics–postclosure). See Table 8.3.4.2-5 for description of major events. This network is consistent with the Draft Mission Plan Amendment (DOE, 1988a) schedule. Revisions will be published in semiannual site characterization progress reports as new information becomes available. (page 2 of 2)

Table 8.3.4.2-5. Major events and planned completion dates for information needs and studies in Issue 1.10 (postclosure waste package characteristics) (page 1 of 6)

Information need/study number	Brief description of information need/study	Major event[a]	Event description	Date
1.10.1	Design information needed to comply with postclosure criteria	A	Continue development of test plans for long-term confirmation testing considering postclosure criteria	10/88
		B	Complete development of test plans for long-term confirmation testing	2/93
1.10.2	Reference waste package designs	A	Complete final waste package design requirements document for advanced conceptual design (ACD)	3/89
		B	Initiate waste package ACD	10/89
		C	Preliminary waste package ACD information information available	2/91
		D	Waste package ACD freeze	9/91
		E	Complete waste package ACD; initiate waste package license application design (LAD)	1/92
		F	Make final selection of material for barrier	2/92
		G	Draft report available to the U.S. Department of Energy (DOE) on waste package ACD	11/92

Table 8.3.4.2-5. Major events and planned completion dates for information needs and studies in Issue 1.10 (postclosure waste package characteristics) (page 2 of 6)

Information need/study number	Brief description of information need/study	Major event[a]	Event description	Date
1.10.2	Reference waste package (continued)	H	Complete waste package design input to repository LAD	11/93
		I	Complete waste package LAD drawings and specifications	1/94
1.10.3	Reference waste package	A	Continue waste-package emplacement-configuration studies	10/88
		B	Information on waste-package emplacement configurations available to Design Activity 1.11.3.3 (vertical and horizontal emplacement orientation decision)	6/89
		C	Complete studies on reference waste-package emplacement configurations	9/89
1.10.4.1 (ongoing)	Characterization of chemical and mineralogic changes in the postemplacement environment	A	Study plan approved	6/89
		B	Initiate dissolution studies of of smectite minerals	7/89
		C	Initiate long-term testing of glass with grout	11/89
		D	Initiate modeling of rock-water interactions using concentrated solution	10/90

Table 8.3.4.2-5. Major events and planned completion dates for information needs and studies in Issue 1.10 (postclosure waste package characteristics) (page 3 of 6)

Information need/study number	Brief description of information need/study	Major event[a]	Event description	Date
1.10.4.1	Characterization of chemical and mineralogic changes in the postemplacement environment (continued)	E	Initial results from rock-water interaction tests using drillcore material provided to modeling	3/91
		F	Complete extraction of vadose water from tuff	12/91
		G	Draft of summary report on single phase dissolution kinetics available to DOE	4/92
		H	Final results of rock-water interactions using candidate repository horizon material available to DOE	7/92
		I	Update waste package environment model with geochemical interactions	3/93
		J	Update models of vadose water/rock interactions	3/93
		K	Update models of dissolution/ precipitation kinetics	3/93
		L	Update models for evaluating corrosion products in the waste package environment	3/93

Table 8.3.4.2-5. Major events and planned completion dates for information needs and studies in Issue 1.10 (postclosure waste package characteristics) (page 4 of 6)

Information need/study number	Brief description of information need/study	Major event[a]	Event description	Date
1.10.4.1	Characterization of chemical and mineralogic changes in the postemplacement environment (continued)	M	Final waste package environment definition provided to waste package performance assessment; initiate revisions to support the license application	3/93
		N	Draft of final report on the effects of grout, concrete, and other materials on waste package environment available to DOE; initiate document revisions to support the license application	9/93
		O	Final report on waste package environment available to DOE	9/93
1.10.4.2 (ongoing)	Determination of hydrologic properties of the waste package environment	A	Study plan approved	3/89
		B	Fracture model input to development of hydrologic flow and transport codes	5/90
		C	Complete two-phase relative permeability test	1/91
		D	Draft of final report on fracture flow studies available to DOE	9/91
		E	Draft of final report on laboratory testing of waste-package environment hydrologic properties available to DOE	12/92

Table 8.3.4.2-5. Major events and planned completion dates for information needs and studies in Issue 1.10 (postclosure waste package characteristics) (page 5 of 6)

Information need/study number	Brief description of information need/study	Major event[a]	Event description	Date
1.10.4.2	Determination of hydrologic properties of the waste package environment (continued)	F	Complete compilation of hydrologic modeling and validation information for input to Issue 1.1 (total system performance assessment)	6/93
		G	Final report on radionuclide source term available to DOE	1/94
1.10.4.3 (ongoing)	Determination of thermal and mechanical attributes of the waste package environment	A	Study plan approved	3/89
		B	Draft report available to DOE on the stability analysis of borehole openings	9/89
		C	Preliminary information on the evaluation of thermal stress on mechanical properties available for incorporation into hydrologic models and transport codes; continue evaluation of thermal stress on mechanical properties for input to report on radionuclide source term	5/90
		D	Complete evaluation of thermal stress on mechanical properties	1/94

Table 8.3.4.2-5. Major events and planned completion dates for information needs and studies in Issue 1.10 (postclosure waste package characteristics) (page 6 of 6)

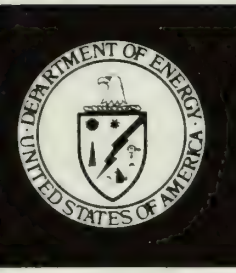
Information need/study number	Brief description of information need/study	Major event[a]	Event description	Date
1.10.4.4	Engineered barrier system field tests	A	Study plan approved	1/90
		B	Draft of preliminary report on the results of the first waste package test available to DOE	7/90
		C	Complete exploratory shaft hardware test for subsequent waste package tests	8/91
		D	Begin waste package environment test installation in the exploratory shaft; near-field thermally-perturbed hydrologic properties tests and rock/water interaction tests will commence following installation and will continue into the confirmatory test phase.	5/92
		E	Final update of the near-field fluid flow and transport model available for waste package environment report	8/93

[a]The letters in this column key major events shown in Figure 8.3.4.2-3.

The overall program schedule presented here is consistent with the Draft Mission Plan Amendment (DOE, 1988a). The site characterization program will undergo a series of refinements following issuance of the statutory SCP. Refinements will consider factors both internal and external to the site characterization program, such as changes to the quality assurance program. Such refinements are to be considered in ongoing planning efforts, and changes that are implemented will be reflected in the semiannual progress reports. Summary schedule information for this and other waste package design issues can be found in Sections 8.5.4 and 8.5.6.

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)



Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.4.3, Waste Package Characteristics (Preclosure)

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.4.3 Issue resolution strategy for Issue 2.6: Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the preclosure design criteria of 10 CFR 60.135 and (b) provide information for the resolution of the performance issues?

Regulatory basis for the issue

This issue deals with two aspects of the waste package design considerations. The first relates to the specific criteria explicitly established in the NRC regulations in 10 CFR 60.135. Compliance with these criteria will be addressed by analyses of the designs and comparison with the criteria under Information Needs 2.6.1 and 2.6.2 (Sections 8.3.4.3.1 and 8.3.4.3.2). Information is also needed on the physical characteristics of the spent fuel and high-level waste that is to be accepted into the disposal system. This information will be provided to the Yucca Mountain Project by other elements of the DOE Office of Civilian Radioactive Waste Management (OCRWM) in the form of waste acceptance specifications, receipt rate projections by waste type and characteristics, and other descriptions. This information is expected to be provided in documents controlled within the OCRWM technical baseline and revised periodically to reflect the most current data available. These specifications and characteristics will reflect the regulatory criteria that establish restrictions on the form and content of the wastes to be received, packaged, and disposed of in the repository. Information Need 2.6.3 (Section 8.3.4.3.3) will accumulate the information for use in the waste package design development.

None of the information needed to address the preclosure waste package design criteria mentioned previously requires the acquisition of site characterization data, as it primarily involves information about, or restrictions on, the waste forms and specific criteria for characteristics of the waste packages.

The second part of this issue is much broader in scope and involves the actual development of the waste package designs and the integration of the designs into the repository system. The approach to resolution of this issue is described in the following section.

Approach to resolving the issue

The approach to be used in resolving this issue is similar to that used in the issues that address design of the repository as described in Section 8.3.2. In that section, the requirements that arise in other issues that involve specific aspects of the repository, for both the preclosure and postclosure periods, are consolidated for design purposes within Issue 4.4 (Section 8.3.2.5). The design is developed and placed in the reference information base. Specific design features are then evaluated for consistency with the requirements for performance as required by the other issues. The testing and design activities described in this section are tentative and are subject to change. Any such change will be reported in semiannual progress reports.

The issues hierarchy (Section 8.2) divides the information needed to develop and evaluate the performance of the waste package designs into five

issues, three of which directly address the design aspects. This division, although logical in the context of the regulatory provisions that place different requirements on the waste packages during the preclosure and postclosure periods, results in a complex design management process because the various requirements are imposed on a single set of physical objects. To integrate the waste package design process, the logic shown in Figure 8.3.4.3-1a has been developed.

In this framework, the design criteria and constraints that are derived within Issue 2.6 from the preclosure functional requirements through the performance allocation process are consolidated with the requirements and other design inputs developed in Issue 1.10 (Section 8.3.4.2). An integrated document, the waste package design requirements, is compiled and provides the definitive guidance for development of the designs.

A significant product of the waste package design effort will be the specification of the production processes to be used in the fabrication, closure, and inspection of the containers. A direct supporting element to the design process is therefore identified separately in Issue 4.3 (Section 8.3.4.4), where the evaluation and testing of these production technologies are described.

The design process is planned to progress through multiple phases, starting with an advanced conceptual design phase and continuing through a license application design phase before submission of a license application. During each of these design phases, the design products, including the supporting analyses, will be transferred to the Yucca Mountain Project reference information base. The design information will then be assessed for compliance with the goals imposed by the appropriate performance issues and transferred to the repository design Issue 4.4 (Section 8.3.2.5). Figure 8.3.4.3-1a also shows the decision paths that must be addressed in the event that performance assessments of the designs indicate that revisions are required to achieve the goals. These assessments will be performed both within the design issue and within the performance issues, as determined by the source of the goal.

Table 8.3.4.3-1 lists the major preclosure functions or characteristics that are derived from the regulatory criteria for the waste packages. Performance measures, goals, and levels of confidence are indicated for these functions needed to resolve this issue (2.6).

The schedule information for Issue 2.6 (preclosure waste package characteristics) is presented in Section 8.3.4.3.4.

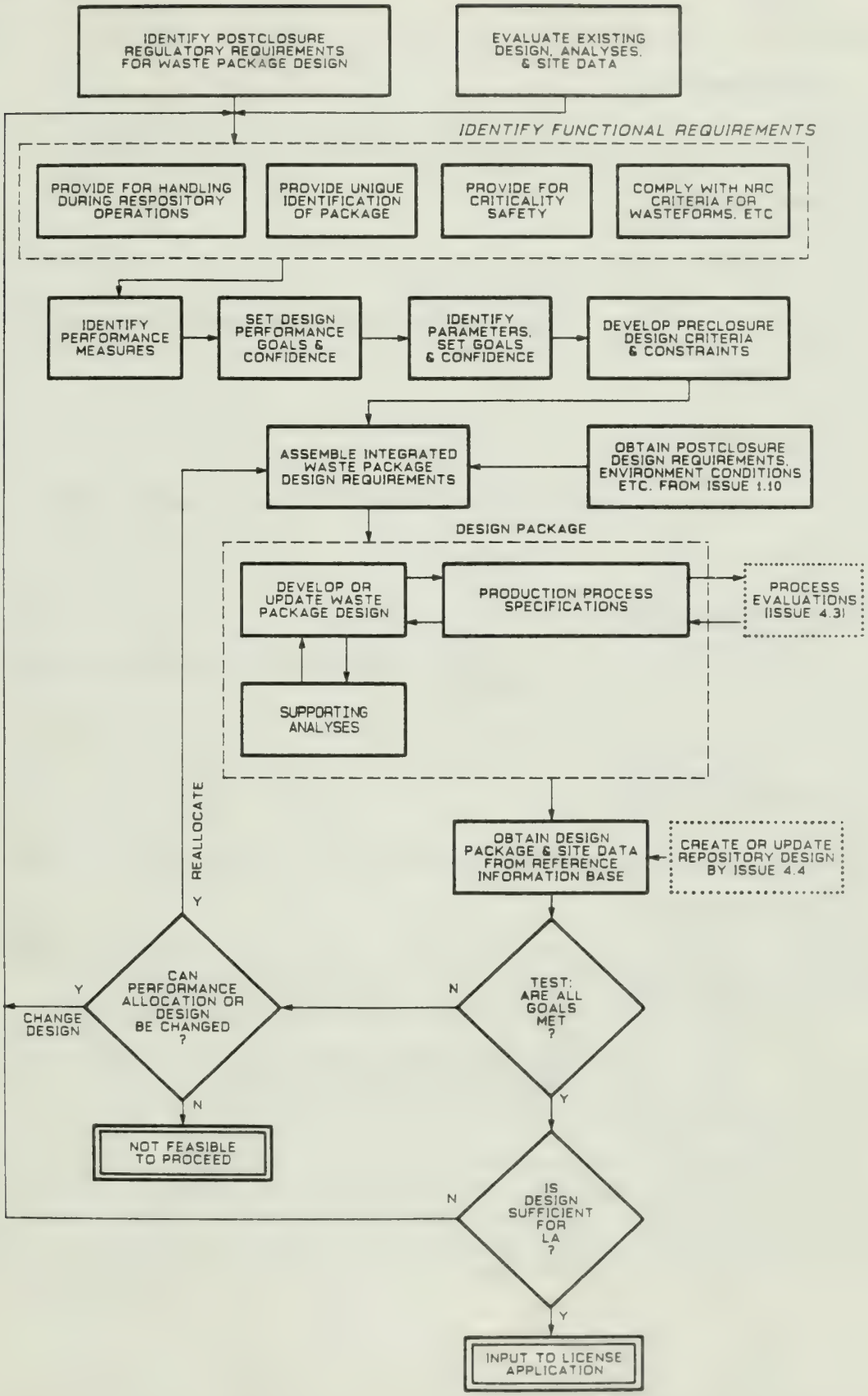
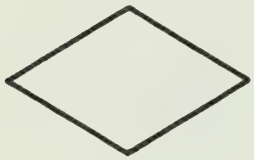


Figure 8.3.4.3-1a. Logic diagram for the resolution of Issue 2.6 (waste package characteristics–preclosure). See Figure 8.3.4.3-1b for legend.

LEGEND



ACTIVITY PERFORMED TO RESOLVE ISSUE



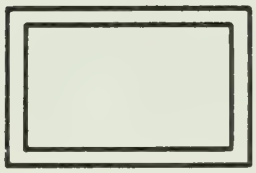
TEST TO DETERMINE SUBSEQUENT ACTIVITY



ACTIVITY PERFORMED BY INDICATED ISSUE



ACTIVITY WITH MULTIPLE SIMILAR ACTIVITIES OR TESTS



DECISION ABOUT ISSUE RESOLUTION

Y - YES
N - NO
LA - LICENSE APPLICATION
NRC - NUCLEAR REGULATORY COMMISSION

Figure 8.3.4.3-1b. Legend for Figure 8.3.4.3-1a

Table 8.3.4.3-1. Performance allocation for Issue 2.6 (waste package characteristics--preclosure)

System element	Function or characteristic	Performance measure	Goal	Confidence needed
Waste package	Contain waste during repository operations	Fraction of containers intact at end of preclosure	>99.5% intact	High
	Limit potential criticality in waste packages	Effective neutron multiplication factor (K_{eff})	<0.95	High
	Provide unique identification of packages	Identification legible at end of preclosure	>99% legible	Medium
Waste form	Comply with NRC criteria for acceptance	Waste form characteristics	>99% (Ci) of waste received in compliance with criteria	High
Container	Capable of being handled by repository systems	Package-handling fixtures	100% through emplacement, >95% through preclosure	High

8.3.4.3.1 Information Need 2.6.1: Design information needed to comply with preclosure criteria from 10 CFR 60.135(b) for materials, handling, and identification of waste packages

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The functional requirements, performance criteria, and constraints derived from the regulatory criteria for this information need and used in the conceptual waste package designs are defined in Section 7.2.1.1, generic preclosure requirements. The preliminary allocation of performance to components in response to these requirements is discussed in Section 7.2.3.1, preclosure performance.

Parameters

The specific waste package design criteria established in 10 CFR 60.135(b)(1) through (4) require that the following parameters be addressed in the design:

1. Explosive, pyrophoric, and chemically reactive materials.
2. Free liquids.
3. Containment during transportation, emplacement, and retrieval.
4. Unique identification.

Logic

The information needed to comply with the criteria of 10 CFR 60.135(b) requires that the waste package designs (together with the characteristics of the waste forms and the preclosure environments that the packages will experience) be analyzed to establish that the criteria will be met. The parameters to be addressed are quite diverse, as are the preclosure environments.

Criteria (1) and (2) in 10 CFR 60.135(b) are limitations on classes of materials in waste packages that could compromise the performance of the packages or other engineered or natural system components. An analysis of the designs, including the waste forms, and the repository operations will be required to show that these classes of materials will not be present or, if present, the quantities will not exceed the criteria.

Criterion (3) is an explicit design requirement that the waste packages maintain waste containment during handling operations. For the waste packages to meet this criterion under all possible loading conditions, the package designs would include structures much stronger than those dictated by any other requirement. An analysis of the containment capability of the waste packages under both normal and off-normal loads will be performed. Loading conditions that result in loss of containment by the packages will be evaluated for significance in view of the repository facility ventilation and other containment systems. These systems are addressed in the information needs under Issue 4.4 (Section 8.3.2.5).

Criterion (4) is an explicit design requirement that each waste package be uniquely identified, with the identifier legible during the preclosure period, consistent with the permanent written records, and that it not impair the integrity of the package. An assessment of the alternatives available for complying with this requirement and an analysis of the selected method will be performed.

The regulatory criteria will be reflected in the waste package design requirements, and the analyses to show that the performance goals have been met will be an integral part of the design activities. The analyses will be documented in the advanced conceptual and license application design reports.

8.3.4.3.1.1 Application of results

The results of the analyses conducted will be used to show compliance with the regulatory criteria and will also be a part of the design information used in the assessment of the performance of the repository system in Issues 2.1 through 2.4 (Section 8.3.5).

8.3.4.3.2 Information Need 2.6.2: Design information needed to comply with preclosure criteria from 10 CFR 60.135(c) for waste forms

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The functional requirement and performance criterion that has been derived from one of the regulatory criteria for this information need is defined in Section 7.2.1.1, generic preclosure requirements. A brief discussion of the waste form design considerations is included in Section 7.2.3.1, preclosure performance. Additional information related to the waste forms is in Section 7.3.1.1, reference waste form descriptions, and Section 7.4.3, waste form research and testing.

Parameters

The specific high-level waste (HLW) form design criteria established in 10 CFR 60.135(c)(1)-(3) require that the following parameters be addressed:

1. Solidification.
2. Consolidation to limit particulates.
3. Combustibles.

Logic

The criteria established in 10 CFR 60.135(c) prescribe three attributes or limitations on the physical form of the HLW to be disposed in the repository. These are reflected in the parameters listed above.

The information needed to demonstrate compliance with these criteria requires that the HLW form designs be analyzed to establish that the criteria will be met. The physical characteristics of the waste forms to be received at the repository for disposal are determined by the DOE waste acceptance specifications. The approach to determining that the waste forms comply with the criteria will be to compare them with the DOE waste acceptance specifications. Therefore, the approach to determining that the waste forms comply with the criteria will be to compare the waste acceptance requirements and specifications obtained in Information Need 2.6.3 (Section 8.3.4.3.3) with the criteria.

One additional criterion is imposed within this section of the regulations that is not strictly related to waste forms. All HLW must be "placed in sealed containers." Although the DOE acceptance requirements for unreprocessed spent fuel do not include this provision, the criterion will be met by

the addition of a sealed container at the repository before emplacement in the underground facility.

This information need will be met by the development of the waste form acceptance specifications (Section 8.3.4.3.3). A documented comparison of these specifications with the regulatory criteria will be presented in the advanced conceptual and license application design reports.

8.3.4.3.2.1 Application of results

This information need provides a comparison to establish compliance with the regulatory criteria and does not have other direct application in the resolution of the issue. The detailed physical characteristics of the waste forms will be addressed in other documents, such as the Office of Geologic Repository generic requirements and will be reflected in the Yucca Mountain Project waste package design requirements.

8.3.4.3.3 Information Need 2.6.3: Waste acceptance specifications

Technical basis for addressing the information need

Link to the technical data chapters and applicable supporting documents

Reference is made to the waste acceptance specifications and requirements in Sections 7.2.3.1 and 7.3.1.1 under discussions of preclosure performance and reference waste form descriptions, respectively.

Parameters

The parameters to be addressed in this information need are

1. Acceptance specifications for unreprocessed spent fuel.
2. Acceptance specifications for West Valley high-level waste.
3. Acceptance specifications for DOE defense high-level waste.

Logic

The characteristics of all waste forms to be received at the repository for packaging and disposal are an essential input to the design and development of the geologic disposal system. Therefore an information need has been identified to provide a mechanism within the issues hierarchy for the development and documentation of these characteristics.

The information to be collected falls into two general classes for each waste form. One is the formal waste acceptance specifications that will be developed by the DOE for determining the acceptability of waste into the OCRWM system. These specifications will determine the parameters to be investigated in the waste form performance testing activities and establish the range of variability of the waste forms. Once established, these acceptance specifications are not expected to change significantly.

The other class of information is the baselined projections of the time-dependent characteristics of the waste streams. These projections are the basis of the waste package and repository designs for packaging and handling facilities and equipment, capacities, and receipt rates. This information is expected to change with time as more accurate projections, especially for waste forms that have not been manufactured yet, become available.

The analyses and activities required to provide the waste acceptance specifications and other waste form characteristics are the direct responsibility of the DOE. Technical support will be provided by the Yucca Mountain Project as appropriate to assist in developing the information. The details of these studies and analyses are beyond the scope of the site characterization plan.

8.3.4.3.3.1 Application of results

The information provided through this information need is central to the basis for resolution of virtually all the waste package design and performance issues. The timely availability of this information is, therefore, critical. It will be maintained and controlled throughout the design and development phase of the project within the Yucca Mountain Project reference information base as a part of the technical baseline.

8.3.4.3.4 Schedule for preclosure waste package characteristics

Issue 2.6 (preclosure waste package characteristics) includes three information needs all of which contain no formally designated activities. However, because Information Need 2.6.1 addresses design information needed to evaluate compliance with regulatory criteria, schedule information for this information need has been included and is summarized in Figure 8.3.4.3-2. This figure includes the information need number and a brief description, as well as major events associated with the information need. A major event, for purposes of this schedule, may represent the initiation or completion of an activity, completion or submittal of a report to the DOE, an important data feed, or a decision point. Solid lines on the schedule represent activity durations and dashed lines show data transferred into or out of this design issue. The events shown on the schedule and their planned dates of completion are provided in Table 8.3.4.3-2.

The schedule, in combination with information provided in the logic diagram for this issue (Figure 8.3.4.3-1), are intended to provide the reader with a basic understanding of the relationships between major elements of the site, performance, and design programs. The information provided in Table 8.3.4.3-2 and Figure 8.3.4.3-2, however, should be viewed as a snapshot in time.

The overall program schedule presented here is consistent with the Draft Mission Plan Amendment (DOE, 1987a). The site characterization program will undergo a series of refinements following issuance of the statutory SCP. Refinements will consider factors both internal and external to the site

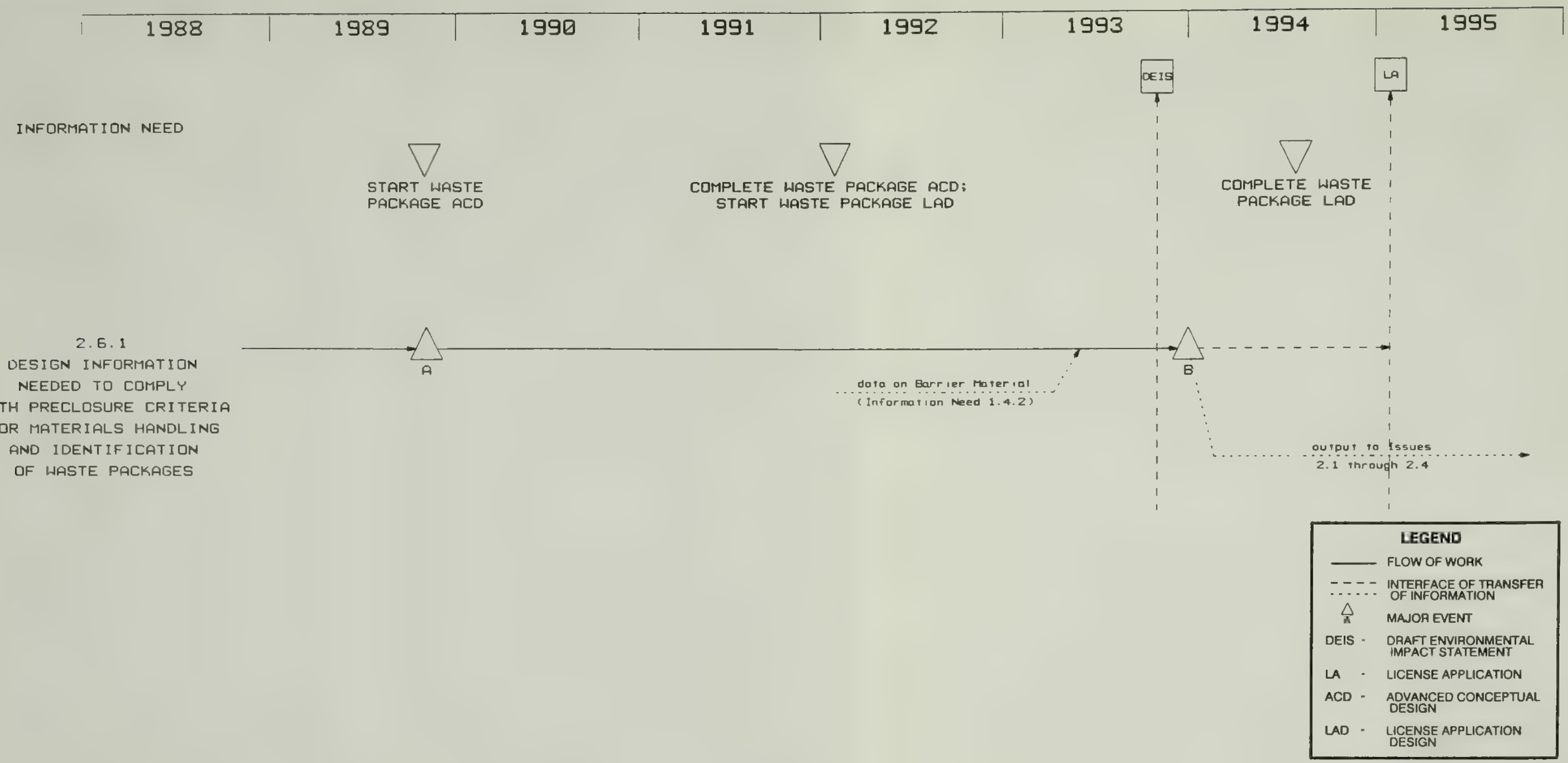


Figure 8.3.4.3-2. Schedule information for Issue 2.6 (waste package characteristics–preclosure) See Table 8.3.4.3-2 for descriptions of major events This network is consistent with the Draft Mission Plan Amendment (DOE, 1988a) schedule Revisions will be published in semiannual site characterization progress reports as new information becomes available

Table 8.3.4.3-2. Major events and planned completion dates for Issue 2.6 (preclosure waste package characteristics)

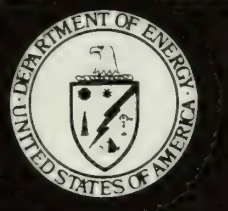
Information need number	Brief description of information need activity	Major event	Event description	Date
2.6.1	Design information needed to comply with preclosure criteria for materials, handling, and identification of waste packages	A	Initiate development of preclosure waste package design requirements for advanced conceptual design	11/89
		B	Final report available to the U.S. Department of Energy on the development of preclosure waste package design requirements for license application design	1/94

[a]The letters in this column key major events shown in Figure 8.3.4.3-2.

characterization program, such as changes to the quality assurance program. Such refinements are to be considered in ongoing planning efforts, and changes that are implemented will be reflected in the semiannual progress reports. Summary schedule information for this and other waste package design issues can be found in Sections 8.5.3 and 8.5.6. Additional related schedule information is presented under Information Need 1.10.2 (Section 8.3.4.2.5.

DOE/RW-0199

Nuclear Waste Policy Act
(Section 113)



Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI, Part B

Chapter 8, Section 8.3.4.4, Waste Package Production Technologies

December 1988

U. S. Department of Energy
Office of Civilian Radioactive Waste Management

8.3.4.4 Issue resolution strategy for Issue 4.3: Are the waste package production technologies adequately established for the resolution of the performance issues?

Regulatory basis for the issue

This issue arises from the provision of 10 CFR 960.5-1, the preclosure system guidelines, that the qualifying conditions require that the repository operation be demonstrated as feasible on the basis of reasonably available technology. The waste packages are a "product" of the repository operation and therefore must be technically feasible on the same basis.

In addition to their technical feasibility, the processes selected for producing the waste packages affect the design of the packages, the design and operation of the repository surface facilities where they are produced, and the performance of the packages after they are emplaced in the repository subsurface facilities.

Rather than differentiate between the feasibility, package and facility design, and package performance aspects of the production processes and describe the plans for each separately, the planned activities to provide information for all these topics are addressed in this issue.

Approach to resolving the issue

Several production technologies are required to fabricate, assemble, and inspect the waste packages. These processes, in addition to being reasonably available, must be responsive to the performance-derived requirements for the waste packages and relevant to the design concepts. Thus, this issue (4.3) is closely coupled to the waste package design requirements document and the design concepts that are generated as a part of Issue 2.6 (Section 8.3.4.3). The relationship between these issues is shown in Figure 8.3.4.4-1. To minimize the interfaces between this issue and other design issues (both for the repository and the waste package), this issue interacts directly only with Issue 2.6.

Interactions with the other design issues are implemented within Issue 2.6 through the Yucca Mountain Project reference information base. These interactions are shown in Figure 8.3.4.4-1.

The approach to resolving this issue will involve a set of studies directed at identifying and evaluating production processes in each of the technology areas. Selection criteria for each technology will be established. Candidate processes will be identified and evaluated against the selection criteria. The leading candidate processes will be used to produce representative test specimens. These test specimens will be analyzed to determine their properties, and the properties will be compared with the criteria derived from the performance requirements. Process selection will then be made on bases that will include performance, as well as other criteria such as reliability, adaptability to repository facility operations, and cost. The final step in the studies will be the use of the selected processes to produce full-scale prototype components and assemblies, including testing of the prototypes to demonstrate both feasibility and compliance with the requirements. The testing and design activities described in this

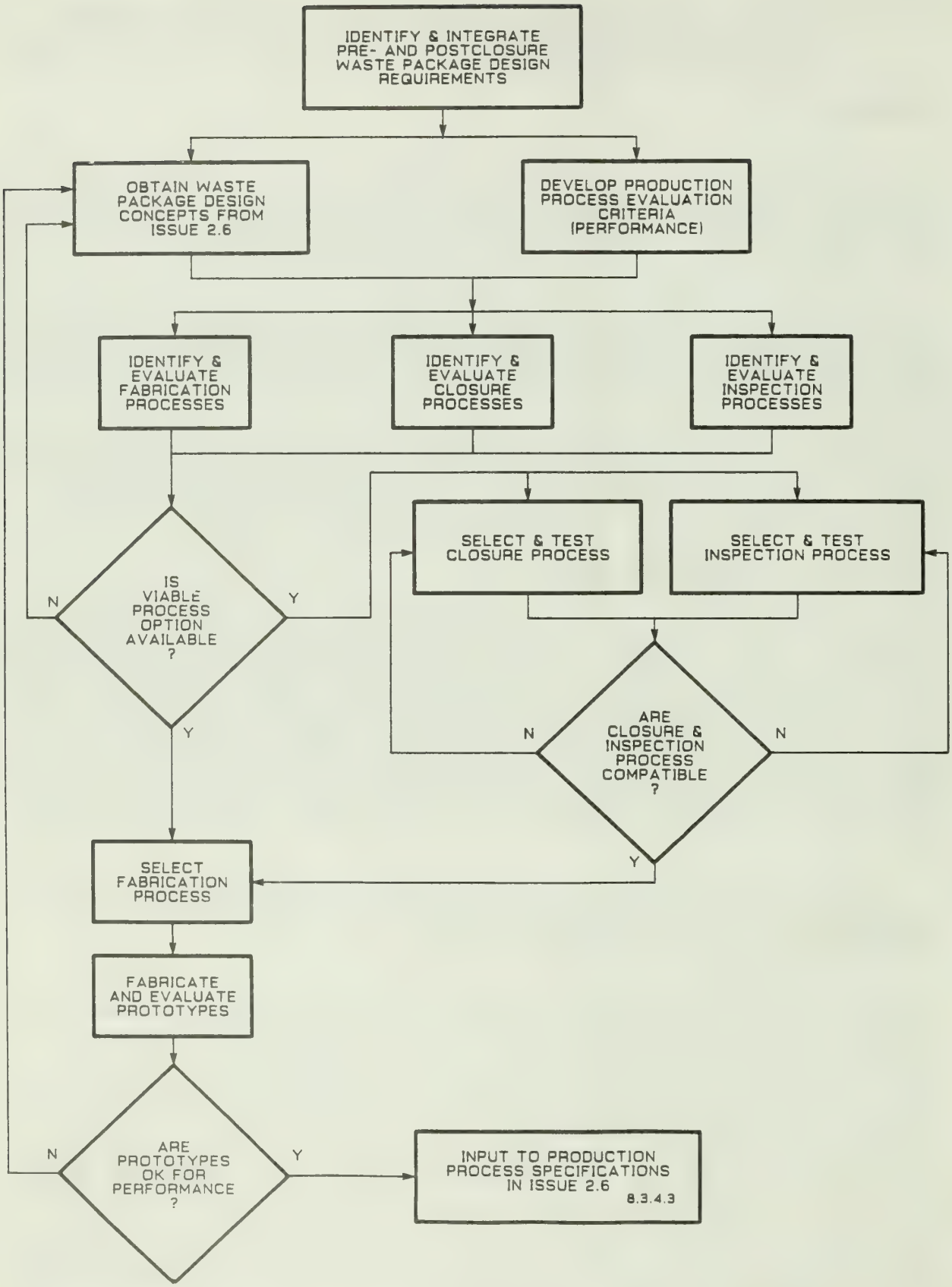


Figure 8.3.4.4-1. Logic diagram for the resolution of Issue 4.3 (waste package production technologies).

section are tentative and are subject to change. Any such change will be reported in semiannual progress reports.

The schedule information for Issue 4.3 (waste package production technologies) is presented in Section 8.3.4.4.2.

8.3.4.4.1 Information Need 4.3.1: Identification and evaluation of production technologies for fabrication, closure, and inspection of the waste package

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

This information need has only an indirect relationship to the characteristics of the site. That relationship is established through the need for the processes selected for production to be responsive to the requirements placed on the waste package design by the anticipated service environment and the performance of the package components. The existing data on this environment is summarized in Section 7.1 and discussed further in Section 7.4.1. The implications of the production processes on the performance of the package components are discussed briefly in Section 7.4.2. A brief discussion of the required processes is found in Section 7.3.1.4.

Parameters

The general parameters to be addressed in this information need are the waste package production technologies. Within each of the technologies, specific parameters associated with the identification, testing, evaluation, selection, and demonstration of the processes are defined. These specific parameters are identified in the activity that addresses each technology.

Logic

The logic to be followed in developing the production technologies is described in the issue resolution section for this issue and follows the conventional approach to production engineering activities as shown in Figure 8.3.4.4-1.

8.3.4.4.1.1 Design Activity 4.3.1.1: Waste package fabrication process development

Objectives

The objective of this activity is to determine, by using the logical sequence described for this issue, the processes to be used in fabricating the nonwaste form components of the waste packages.

Parameters

The parameters of this activity involving fabrication technologies are

1. Requirements and selection criteria.
2. Candidate process identification.
3. Process testing.
4. Process evaluation.
5. Process selection.
6. Prototype fabrication and testing.

Description

Fabrication is defined as those processes required to produce the package components other than the waste forms. These components are assumed to be produced at commercial facilities and, after inspection to ensure compliance with procurement specifications, delivered to the repository for assembly. The processes to be used may include production of container and other component materials; forming and joining processes such as rolling, welding, casting, forging, extruding, or combinations of these; heat treating; nondestructive testing and inspection; and packaging, shipping, and storage.

Each of the applicable process steps will be evaluated, and a process will be selected and demonstrated as necessary to show compliance with the requirements established for each package component.

8.3.4.4.1.2 Design Activity 4.3.1.2: Waste package closure process development

Objectives

The objective of this activity is to determine, by using the logical sequence described for this issue, the process to be used in the final closure of the waste package containers.

Parameters

The parameters of this activity involving closure technologies are

1. Requirements and selection criteria.
2. Candidate process identification.
3. Process testing.
4. Process evaluation.
5. Process selection.
6. Full-scale demonstration.

Description

The closure process is required to provide a high-integrity seal of the containers. The closure must be performed under hot cell conditions by equipment operated by remote control. Additional requirements will be

imposed by the need for a highly reliable process that can be qualified on the basis of monitored process variables and remote equipment maintenance. The process may be a conventional joining process or may require developments of the state of the art.

The candidate closure processes will be evaluated, and a process will be selected and demonstrated as necessary to show compliance with the requirements established for final package closure.

8.3.4.4.1.3 Design Activity 4.3.1.3: Waste package closure inspection process development

Objectives

The objective of this activity is to determine, by using the logical sequence described for this issue, the process to be used in the inspection of the final closure of the waste package containers.

Parameters

The parameters of this activity involving inspection technology are

1. Requirements and selection criteria.
2. Candidate process identification.
3. Process testing.
4. Process evaluation.
5. Process selection.
6. Prototype subsystem design and specification.

Description

Following the final closure of the waste package containers, the integrity of the closure will require a verification by a nondestructive inspection. This inspection process, which will also be made by equipment operated by remote control, must operate with high reliability to ensure adequate defect detection and yet avoid false rejections. The high ionizing radiation field present will limit the alternatives available for this process.

The candidate closure inspection processes will be evaluated, and a process will be selected and demonstrated as necessary to show compliance with the requirements established for closure inspection. An inspection subsystem will be designed and specified for this process.

8.3.4.4.1.4 Application of results

The results of this study will be used directly to resolve this issue (4.3). Additionally, they will be used interactively with information from the waste package design development in Issue 2.6 (Section 8.3.4.3) to establish the production process specifications, which are an integral part of the design documentation.

8.3.4.4.2 Schedule for waste package production technologies

Issue 4.3 (waste package production technologies) includes one information need, which contains three design activities. The schedule information for these design activities is summarized in Figure 8.3.4.4-2. This figure includes the design activity number and a brief description, as well as major events associated with each activity. A major event, for purposes of these schedules, may represent the initiation or completion of an activity, completion or submittal of a report to the DOE, an important data feed, or a decision point. Solid lines on the schedule represent activity durations and dashed lines show interfaces among activities as well as data transferred into or out of this design issue. The events shown on the schedule and their planned dates of completion are provided in Table 8.3.4.4-1.

The activity-level schedules, in combination with information provided in the logic diagram for this issue (Figure 8.3.4.4-1), are intended to provide the reader with a basic understanding of the relationships between major elements of the site, performance, and design programs. The information provided in Table 8.3.4.4-1 and Figure 8.3.4.4-2, however, should be viewed as a snapshot in time.

The overall program schedule presented here is consistent with the Draft Mission Plan Amendment (DOE, 1988a). The site characterization program will undergo a series of refinements following issuance of the statutory SCP. Refinements will consider factors both internal and external to the site characterization program, such as changes to the quality assurance program. Such refinements are to be considered in ongoing planning efforts, and changes that are implemented will be reflected in the semiannual progress reports. Summary schedule information for this and other waste package design issues can be found in Sections 8.5.3 and 8.5.6.

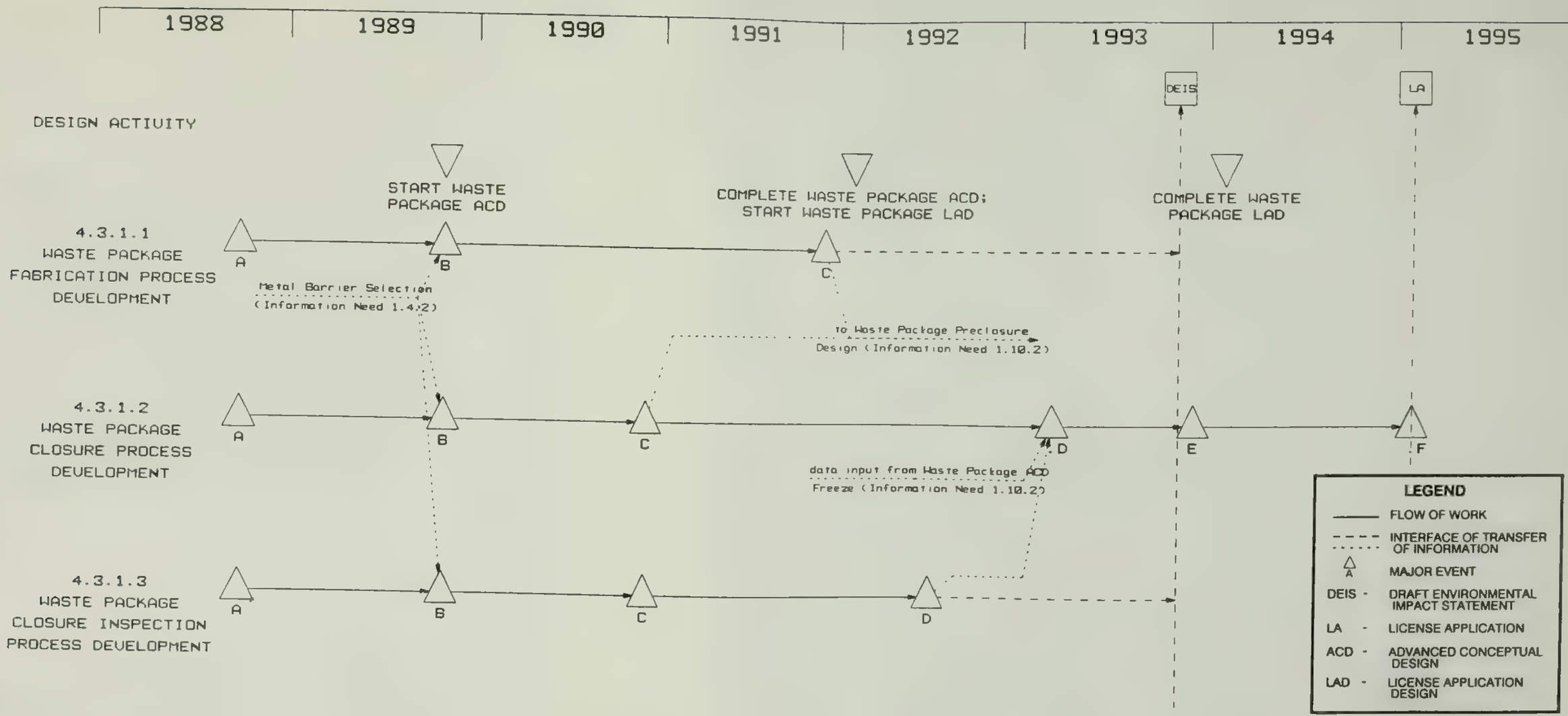


Figure 8.3.4.4-2. Schedule information for design activities in Issue 4 3 (waste package production technologies) See Table 8 3 3 4-1 for description of major events This network is consistent with the Draft Mission Plan Amendment (DOE. 1988a) schedule Revisions will be published in semiannual site characterization progress reports as new information becomes available.

Table 8.3.4.4-1. Major events and planned completion dates for design activities in Issue 4.3 (waste package production technologies) (Page 1 of 2)

Design activity number	Brief description of design activity	Major event	Event description	Date
4.3.1.1	Waste-package fabrication process development	A	Continue waste-package fabrication process development	10/88
		B	Receive data on metal barrier selection and continue waste-package fabrication process development	10/89
		C	Complete report on container fabrication process development	11/91
4.3.1.2	Waste-package closure process development	A	Continue waste-package closure process development	10/88
		B	Receive data on final waste-package advanced conceptual design (ACD) requirements and metal barrier selection; continue waste-package closure process development	10/89
		C	Complete report on container closure process development	11/90
		D	Begin preparation of reports, plans, and procedures for waste-package prototype fabrication process	2/93

Table 8.3.4.4-1. Major events and planned completion dates for design activities in Issue 4.3 (waste package production technologies) (Page 2 of 2)

Design activity number	Brief description of design activity	Major event	Event description	Date
4.3.1.2	Waste-package closure process development (continued)	E	Complete fabrication of waste package prototype; initiate demonstration tests of waste package prototype	11/93
		F	Complete engineering tests of ACD prototype waste package	1/95
4.3.1.3	Waste-package closure inspection process development	A	Continue waste-package closure inspection process development	10/88
		B	Receive data on metal barrier selection; continue waste-package closure inspection process development	10/89
		C	Complete report on waste-package closure inspection development	11/90
		D	Complete preparation of plans and procedures for waste-package closure inspection process for inclusion in report on waste-package prototype fabrication process	6/92

[a]The letters in this column key major events shown in Figure 8.3.4.4-2.

The following number is for OCRWM Records Management purposes only and should not be used when ordering this publication.

Accession Number: HQO.881201.0002